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Market Diseases of Stone Fruits: Cherries, Peaches, Nectarines, Apricots, and Plums

Agriculture Handbook No. 414



Agricultural Research Service
UNITED STATES DEPARTMENT OF AGRICULTURE

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By JOHN M. HARVEY, WILSON L. SMITH, JR.,
and JACOB KAUFMAN

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Preface

This handbook is an extensive revision of and supersedes Miscellaneous Publication No. 228, *Market Diseases of Fruits and Vegetables: Peaches, Plums, Cherries, and Other Stone Fruits*, by Dean H. Rose, D. F. Fisher, Charles Brooks, and C. O. Bratley. This handbook is one of a series designed to aid in the recognition and identification of market diseases, to provide information on factors causing the diseases, and to present control measures for reducing the economic losses caused by these diseases during marketing.

The handbook is designed for use by market inspectors, research workers, shippers, receivers, carriers, and others concerned with maintaining the quality of fresh foods during marketing.

Other publications in this series are:

Agriculture Handbooks

- 28. *Market Diseases of Tomatoes, Peppers, and Eggplants.* June 1952. (Revised February 1968.)
- 155. *Market Diseases of Beets, Chicory, Endive, Escarole, Globe Artichokes, Lettuce, Rhubarb, Spinach, and Sweetpotatoes.* April 1959. (Reprinted May 1967.)
- 184. *Market Diseases of Cabbage, Cauliflower, Turnips, Cucumbers, Melons, and Related Crops.* September 1961.
- 189. *Market Diseases of Grapes and Other Small Fruits.* November 1960. (Reprinted April 1966.)
- 303. *Market Diseases of Asparagus, Onions, Beans, Peas, Carrots, Celery, and Related Vegetables.* September 1966.
- 376. *Market Diseases of Apples, Pears, and Quinces.* May 1971.
- 398. *Market Diseases of Citrus and Other Subtropical Fruits.* (In press.)

PRECAUTIONS

Pesticides used improperly can be injurious to man, animals, and plants. Follow the directions and heed all precautions on the labels.

Store pesticides in original containers under lock and key—out of the reach of children and animals—and away from food and feed.

Apply pesticides so that they do not endanger humans, livestock, crops, beneficial insects, fish, and wildlife. Do not apply pesticides when there is danger of drift, when honey bees or other pollinating insects are visiting plants, or in ways that may contaminate water or leave illegal residues.

Avoid prolonged inhalation of pesticide sprays or dusts; wear protective clothing and equipment if specified on the container.

If your hands become contaminated with a pesticide, do not eat or drink until you have washed. In case a pesticide is swallowed or gets in the eyes, follow the first aid treatment given on the label, and get prompt medical attention. If a pesticide is spilled on your skin or clothing, remove clothing immediately and wash skin thoroughly.

Do not clean spray equipment or dump excess spray material near ponds, streams, or wells. Because it is difficult to remove all traces of herbicides from equipment, do not use the same equipment for insecticides or fungicides that you use for herbicides.

Dispose of empty pesticide containers promptly. Have them buried at a sanitary land-fill dump, or crush and bury them in a level, isolated place.

NOTE: Some States have restrictions on the use of certain pesticides. Check your State and local regulations. Also, because registrations of pesticides are under constant review by the U.S. Department of Agriculture, consult your county agricultural agent or State Extension specialist to be sure the intended use is still registered.

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MARKET DISEASES OF STONE FRUITS

Cherries, Peaches, Nectarines, Apricots, and Plums

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INTRODUCTION

The market diseases of cherries (*Prunus avium* L.), peaches (*P. persica* (L.) Batsch), nectarines (*P. persica* (L.) Batsch var. *nectarina* (Ait.) Maxim.), apricots (*P. armeniaca* L.), plums (*P. salicina* Lindl.), and prunes (*P. domestica* L.) are discussed in this publication. The diseases are divided into two groups, the parasitic diseases and the nonparasitic diseases or disorders. Parasitic diseases are those caused by pathogenic organisms (fungi and bacteria) and viruses. Nonparasitic diseases are those caused by physical forces (bruising or freezing), physiological effects (internal breakdowns or shriveling), other nonpathogenic factors, and by insects.

The parasitic diseases are further separated on the basis of host fruit—diseases of cherries, diseases of peaches, nectarines, and apricots, and diseases of plums (and prunes). Diseases of each of these fruits, or groups of fruit, are arranged by causal factor. Frequently a particular organism will cause disease in more than one host. In such cases, the symptoms of the disease are given for each host, but details about the causal organism and control are given only for the host on which the disease is most common or of greatest economic importance. Cross-references are provided, which enable the reader to obtain additional information about the cause and control of the disease.

In this handbook, nonparasitic diseases are separated into three groups—diseases that are orchard and weather related, those that are storage related, and those that are transit and handling related. The causes of nonparasitic disorders cannot always be clearly defined, so that these disorders are arranged primarily on the basis of symptom expression (cracking, russeting, shriveling).

Each disease is considered in respect to its geographical distribution, where it occurs in marketing channels, its economic importance, varietal susceptibility or resistance, external and internal symptom expression, causal factors, temperature relations, and control measures. For parasitic diseases, consideration also is given to the mode of infection, where and when it takes place, predisposing factors to infection, dissemination of the disease, and how it may be related to other disorders (bruising).

Control of market diseases or prevention of disorders is considered primarily in relation to postharvest handling, storing, and shipping practices. Orchard treatments vary with the locality, and instruction on such control measures should be obtained from farm advisors or county agents serving the pertinent production area. Available information is given on control or reduction of disease losses by proper refrigeration practices, controlled atmospheres, fungicide treatments, heat treatments, or packaging.

Injurious insects sometimes cause disorders of stone fruits that resemble certain parasitic diseases or orchard-related nonparasitic disorders. Insect injuries that may be confused with these market diseases are described; injuries that obviously are the direct result of boring or chewing insects are not included in this handbook.

PARASITIC DISEASES OF STONE FRUITS

Cherries

Alternaria Rot

Alternaria sp.

Occurrence and symptoms

Alternaria rot is a common market disease of the principal varieties of sweet cherries grown in California and the Northwest and of sour cherries grown in Michigan.

Alternaria rot of cherries is dark brown to black, firm, and slightly moist. The affected area appears as a spot on the surface of the fruit and may be covered with olive-green spores and white strands of mold. The rotted tissue beneath the spot is cone shaped, with the apex of the cone extended toward the pit. The cone separates readily from the surrounding tissue and can be lifted out.

The symptoms of alternaria rot are similar to those of clado-

sporium rot, but in the former the surface mold is darker, the decayed tissue more moist and dark, and the enlargement of the lesions more rapid (pl. 1, A).

Causal factors

The fungus, *Alternaria*, is widespread in nature, growing on dead leaves, twigs, and other material in the orchard. The spores are windborne and on germination, the fungus enters the cherry through breaks in the skin caused by cracking in the orchard or wounding during picking and packing.

Most species of *Alternaria* causing fruit rot grow best at about 77° F. and grow very slowly at 32° F.

Control measures

Since the fungus is less active at low than at moderate or high temperatures, cherries should be precooled as soon after harvest as possible and stored or transported as close as possible to the recommended holding temperature of 31° to 32° F. Careful handling to prevent bruising or wounding during picking, packing, and loading would make the fruit less subject to infection.

Decay in stored cherries also has been reduced by modified atmospheres in which the carbon dioxide (CO₂) level is held at 10 percent. Packing the fruit in boxes with polyethylene liners has been effective in maintaining a high CO₂ level in atmospheres in transit and marketing.

(See 72, 73, 114, 162, 186.)¹

Black Mold Rot

Aspergillus niger v. Tiegh.

Black mold rot of cherries is rarely found on the market. Rot caused by this mold is watery and mushy and can be scooped out, leaving a clean cavity in the surrounding flesh. The surface of the affected area becomes cracked and small white tufts of mold appear. As spores are produced, the mold turns jet black.

Aspergillus niger grows best at 86° to 98° F. and grows very little at temperatures below 45°. The disease, therefore, is of little consequence when cherries are properly refrigerated.

See Peaches, Nectarines, and Apricots, page 12.

(See 160, 186.)

¹ Italic numbers in parentheses refer to Literature Cited, p. 50.

Blue Mold Rot

Penicillium expansum Lk. ex Thom.

Occurrence and symptoms

Blue mold rot is one of the most important disorders of cherries on the market. It is particularly prevalent in fruit that has been exposed to rainfall or high moisture conditions in the orchard. Such conditions may cause cracking of the skin, which predisposes the fruit to infection. The Bing and Tartarian varieties are particularly susceptible to cracking; Lambert is less susceptible. Generally, large-fruited varieties tend to crack more readily than small-fruited varieties and susceptibility to cracking increases as the fruit matures.

Externally, blue mold rot first appears as a circular, flat, light-brown area. Internally, the affected tissue is very soft and watery. As the rot develops, the skin covering it cracks readily and small, white tufts of the mold appear. Under humid conditions, the mold grows over the surface of the rotted area and soon produces a crop of bluish-green spores. In the late stages of decay, affected cherries become crushed during handling and the decayed tissues contaminate surrounding fruit (pl. 1, B).

Causal factors

Blue mold rot is caused primarily by the fungus, *Penicillium expansum*, although some other species of *Penicillium* may be associated with the disease. This fungus produces a large number of spores, which are widely disseminated in the air. *Penicillium* seldom infects the fruit through the intact skin, but enters through cracks caused by moisture or injuries during harvesting and packing. Susceptibility increases as the fruit matures.

Penicillium expansum grows best at about 77° F. and growth almost ceases at 32°. The spores germinate readily at 77°, but germination is greatly delayed (7 to 14 days) at 32°.

Control measures

Since growth of the causal fungus is greatly reduced at low temperature, rapid precooling and storage at 31° to 32° F. are effective in reducing losses from blue mold rot. Temperatures in transit should be maintained as close to 32° as possible.

High CO₂ levels in atmospheres also reduce the development of blue mold rot in cherries. A 20-percent level of CO₂ at 36° or 45° F. has been found to have about the same inhibitory effect on the

development of blue mold rot as a temperature of 31° without CO₂. High CO₂ levels in atmospheres can be achieved in transit by using polyethylene liners in the boxes in which cherries are packed or by adding 800 to 1,000 pounds of dry ice to the refrigerator car used to transport the fruit.

Preventing skin punctures or bruising during harvesting and handling will reduce infection ports for blue mold.

(See 63, 70, 72, 73, 141, 152, 186, 187, 193, 211.)

Brown Rot

Monilinia fructicola (Wint.) Honey and *M. laxa*

(Aderh. & Ruhl.) Honey

Occurrence and symptoms

Brown rot is an important disease of cherries, particularly in humid or wet seasons when it may affect up to one-third of the crop. The disease is found on cherries grown in California, the Northwest, and in other areas of the United States. Brown rot affects fruit in the orchard and during transit and marketing.

The rot is light brown at first, but darkens later. The margins of the affected area fade into the normal fruit color, leaving no distinct line separating decayed from healthy tissue. The skin covering the rot remains firmly attached to the tissue beneath. Brownish-gray masses of spores are produced quickly on the surface of decayed portions of the fruit. At room temperature, the decay spreads rapidly over the affected fruit and to adjacent fruits (pl. 1, C).

Causal factors and control measures

See Peaches, Nectarines, and Apricots, pages 15 and 16.

(See 25, 32, 34, 65, 125, 202, 211.)

Cladosporium Rot

Cladosporium herbarum Lk. ex Fr.

Occurrence and symptoms

Cladosporium rot causes serious losses in sweet cherries during seasons in which weather conditions cause cracking of the skin. Cherries from California and the Pacific Northwest are frequently affected.

The decayed area is usually small, often affecting only the lining

of the crack or wound around which it centers. The decayed tissue is hard, dry, gray to black, and cone shaped with its apex extending deep into the fruit. This cone can be easily removed from the surrounding healthy tissue. External signs of the fungus are a thin, fluffy growth of white mold that covers the decayed area and that produces abundant yellowish-olive spores (pl. 1, *D*).

Causal factors

Cladosporium herbarum, the causal fungus, is widespread in nature, growing and sporulating abundantly on dead plant materials. Decay caused by the fungus develops most rapidly at about 72° F., but also develops slowly at storage temperatures as low as 34°. Other organisms frequently gain entrance through the same wounds and mask the primary symptoms of cladosporium rot.

Control measures

An important control measure for this disease is the prevention of wounds, because the causal fungus enters the fruit only through breaks in the skin. Careful sorting to remove cracked fruit at the packinghouse and rapid cooling will reduce the incidence and development of decay. Maximum refrigeration should be maintained in transit to provide temperatures as close to 32° F. as possible.

(See 25, 160.)

Coryneum Blight

Coryneum carpophilum (Lev.) Jauch.

Occurrence and symptoms

Coryneum blight is primarily a disease of cherries and other stone fruits grown in the Western United States and is rarely found in the East. The disease is most evident on the leaves where it causes spots or "shothole," but the organism also attacks the fruit, causing small dry spots. The flesh below these spots is affected with rot that gradually extends to the pit or may spread over the whole fruit.

Causal factors and control measures

See Peaches, Nectarines, and Apricots, page 18.

(See 83, 87, 136, 160, 203, 204.)

Gray Mold Rot

Botrytis cinerea Pers. ex Fr.

Occurrence

Gray mold rot is frequently found on cherries from all producing areas in the United States. Inspection records over a period of several years have shown that an average of almost 0.5 percent of the cherries arriving at eastern markets have had gray mold rot. The disease is much more prevalent in years when cool, moist weather occurs shortly before harvest.

Symptoms

Gray mold rot first appears as a light-brown spot on the skin. The spot later becomes covered with a delicate growth of *Botrytis cinerea*, the causal fungus, and the underlying tissue becomes somewhat watery and a darker brown. As the decayed area enlarges, the fungus growth becomes more prominent. Under relatively dry conditions, gray spores are produced abundantly over the decayed areas of the fruit; under moist conditions, as in a box of cherries with a film liner, an abundant white growth of fungus may cover the affected fruits and spread to adjacent ones. The skin near the margins of decayed areas slips easily under pressure from the finger, as in rhizopus rot, but the decayed tissue does not have the sour odor characteristic of rhizopus rot—gray mold has no definite odor. Spread of the fungus by contact from infected to sound fruits often occurs, resulting in nests of molded fruit in a box (pl. 1, *E*).

Causal factors

Gray mold rot is caused by the fungus, *Botrytis cinerea*, which causes decay in many different fruits, vegetables, and other crops. This fungus may enter the fruit through breaks in the skin or may penetrate the skin after growing on dead flower parts or other plant debris adhering to the surface of the fruit.

Botrytis cinerea grows best at 72° to 77° F. and fruit rot develops rapidly at these temperatures. Slight growth occurs at 32° and decay may increase slowly even at this low temperature. A 50-percent reduction in growth of *Botrytis* occurs when 20 percent CO₂ is added to the atmosphere, and spore germination is completely inhibited in atmospheres with a CO₂ level of 32 percent.

Control measures

Careful handling during picking and packing and elimination of culls and rotted fruit are effective methods of reducing market losses from gray mold. A comparison of cherries handled commercially and those especially handled to prevent bruising showed that almost four times as much gray mold rot developed in the commercially handled fruit.

Prompt precooling after harvest greatly reduces the development of gray mold. Atmospheres with a CO₂ level of 10 percent have been found to reduce decay and extend storage life. Film liners are effective in retaining CO₂ during transit or dry ice may be used to build up the CO₂ level in the atmospheres. Certain postharvest fungicidal dips have been found effective in reducing gray mold rot.

(See 73, 162, 200, 202, 211, 212.)

Rhizopus Rot

Rhizopus stolonifer (Ehr. ex Fr.) Vuill.

Occurrence

Rhizopus rot is one of the most important postharvest diseases of cherries. A survey indicated that an average of 0.7 percent of the cherries reaching the New York market were affected by this disease. The incidence of rhizopus rot increases as the fruit ripens; cracks or bruises in the skin also favor the disease.

Symptoms

Rhizopus rot first appears as water-soaked, tender, slightly darkened areas on the fruit. Later the entire fruit breaks down, producing a red, loose mass of rotted tissue covered with an abundant coarse growth of the fungus. Dull, black fruiting bodies of the fungus are produced over the surface. The mold quickly spreads over large parts of a box of fruit and may involve the entire contents. Watery, red juice may drip from such cherry boxes (pl. 1, F).

Causal factors

See Peaches, Nectarines, and Apricots, page 23.

Control measures

Since *Rhizopus stolonifer* is a "high temperature" organism, it is best controlled by cooling the fruit promptly and holding it at

low temperature in transit or in storage. The causal organism ceases to grow at temperatures below 45° F. Maximum refrigeration is recommended in transit, with temperatures as near 32° as possible.

Controlled or modified atmospheres also have been effective in reducing rhizopus rot. Spore germination is completely inhibited in atmospheres with 8 percent CO₂ and vegetative growth of the mold is reduced by one-half in those with 20 percent CO₂. Atmospheres with 10 percent CO₂ have reduced decay of cherries in storage tests. Atmospheres with high levels of CO₂ can be obtained in transit by using polyethylene box liners or by using dry ice in refrigerated railcars or trailers. From 800 to 1,000 pounds of wrapped dry ice can be placed in a crib above the brace of a car, with an additional 200 pounds broken up in the ice bunkers of the car. In trucks the wrapped dry ice is suspended well above the load to prevent freezing.

(See 70, 71, 72, 73, 141, 152, 162, 200.)

Peaches, Nectarines, and Apricots

Alternaria Rot

***Alternaria* sp.**

Occurrence and symptoms

Alternaria rot may occur on peaches, nectarines, and apricots when these fruits are stored for long periods at low temperature. The disease is rarely found on freshly harvested fruit.

Alternaria rot is black to greenish black, firm, slightly sunken, and moist, and usually affects only the surface of the fruits. In advanced stages, the affected areas may be covered with olive-green spores of the fungus and the rot may extend deeper into the flesh, forming a cone that can easily be scooped out (pl. 2, A; pl. 3, D).

Causal factors and control measures

See Cherries, page 3, and Plums, page 27.

Anthraxnose (Bitter Rot)

***Glomerella cingulata* (Ston.) Spauld. & Schrenk.**

Occurrence

Anthraxnose has been an important disease of peaches in Japan since 1920. It was first observed in the United States in ship-

ments of peaches from Georgia in 1947. In succeeding years, the disease became serious in most Southeastern peach-growing States and later was reported on peaches grown in most States on the east coast and in the Midwest. The disease caused serious losses from 1947 to about 1955, but since that time has become less important.

Peaches infected with anthracnose are usually detected when the fruit is harvested and diseased fruit is discarded during packing-house operations. However, some incipient infections escape detection and cause losses during marketing.

Symptoms

The first symptoms of anthracnose on peach fruit are one or more small, circular, brown spots, $\frac{1}{8}$ to $\frac{1}{4}$ inch in diameter. These spots occur indiscriminately over the surface of the fruit and closely resemble the early stages of brown rot. In the early stages, the spots may be slightly moist, but usually they are firm and dry. The spots slowly enlarge to about 1 inch in diameter and the tissue beneath collapses, causing a depression to form in the center. In advanced stages, the depressed area may extend $\frac{1}{8}$ to $\frac{1}{4}$ inch into the flesh. The affected area is surrounded by a firm, circular margin. A fine, grayish growth of the fungus may cover the spots and later concentric rings of salmon-pink spore masses are produced in the depression. In severe infections, the spots may coalesce and cover a large part of the fruit (pl. 4, G).

Causal factors

The causal fungus, *Glomerella cingulata*, is the same organism that causes bitter rot of apples. The fungus overwinters in blue lupine in the Southern States and infects peaches in the early stages of growth in the spring. Infections also may occur in later stages of growth and damage from the disease becomes apparent as the fruit approaches maturity. Two strains of the organism exist, one having a pink and the other a gray vegetative growth. The pink strain grows more rapidly and causes decay to develop faster than the gray strain at temperatures below 50° F. No growth occurs with either strain at temperatures below 40° or above 95°. The optimum temperature for growth of both strains is 80°.

Control measures

Since the symptoms of anthracnose are often apparent when peaches arrive at packing sheds, careful grading will eliminate most diseased fruit from the market. Storage and transit tem-

peratures near or below 40° F. will prevent further development of the decay. In regions where the blue lupine is used as a winter cover crop, the elimination of this host has done much to reduce losses and to minimize the importance of anthracnose as a market disease.

(See 61, 138, 149, 178, 197.)

Bacterial Spot

Xanthomonas pruni (E. F. Sm.) Dows.

Occurrence

Bacterial spot is a serious disease of peaches, nectarines, and apricots. Commercially it is most important as a disease of peaches, causing losses in the eastern and mid-western parts of the United States, but not in fruit-growing sections west of the Rocky Mountains. The disease also occurs in Australia, Brazil, Canada, Japan, New Zealand, and Russia. Most varieties of peach are susceptible to bacterial spot, particularly Sun High and late-maturing varieties Elberta or J. H. Hale. Losses from bacterial spot are reflected not only in damaged fruit, but also in reduced yields resulting from defoliation of trees affected with the disease.

Symptoms

Bacterial spot appears as circular, faint, brown spots about 0.5 to 1.0 mm. in diameter on maturing peach fruits in the orchard. As the spots enlarge, the centers darken slightly and become sunken; the margins of the spots have a watersoaked appearance. Spots may occur on any area of fruit, thus differing from scab, which occurs mostly at the stem end. The spots sometimes coalesce and cover large areas. Numerous types of skin cracking may occur. Fruits infected at an early stage of development usually are more malformed than those infected later. Cracks in the fruit range from very small and shallow cracks with a greenish halo to deep, open cracks containing a yellowish, gummy exudate. This exudate also may be produced in large spots and often dries into hornlike projections (pl. 5, A and B).

Causal factors

Xanthomonas pruni overwinters in infected twigs and in the spring is spread mainly by wind and rain to leaves and fruits. The bacterium infects blossoms or the unbroken skin of the fruit. It grows luxuriantly at temperatures between 75° and 83° F. and may cause severe infection in the orchard between 70° and 85°.

Growth of the organism is reduced above 85° and the bacterium ceases to multiply at 100°. It is killed in 10 minutes when exposed to a 124° temperature. Fruit on weak trees are more susceptible to attacks by *X. pruni* than fruit on vigorous trees.

Control measures

Since bacterial spot is primarily an orchard disease, affected fruit should be graded out in the packinghouse. Postharvest treatments do not reduce the disease. Control measures in the orchard include proper chemical spray applications and good cultural practices necessary to produce vigorous trees.

(See 7, 8, 56, 58, 92, 102, 110, 118, 121, 159.)

Black Mold Rot

Aspergillus niger v. Tiegh.

Occurrence

Black mold rot of peach, nectarines, and apricots occurs occasionally on all varieties of these fruits, but never causes serious losses. Most commonly it attacks fruit during warm ripening periods following prolonged storage or transit. Black mold rarely occurs on freshly harvested fruit.

Symptoms

Early symptoms of black mold rot on peaches are small, tan, slightly sunken spots at various places on the fruit. As the spots enlarge, the tan skin becomes wrinkled in concentric circles. Later a scant, white growth of mold appears near the center of the spot and then spreads over the affected area. The mold produces abundant spores that are yellow at first, but soon turn black, giving the rot a sooty appearance. Sometimes the sooty area is surrounded by a scant, white growth of mold and tan discolored skin. The flesh $\frac{1}{8}$ to $\frac{1}{4}$ inch beneath the affected area turns brown and mushy and can be scooped out, leaving a saucerlike hollow surrounded by healthy tissue (pl. 4, A and B).

Causal factors

The causal fungus, *Aspergillus niger*, is widespread in nature, growing on organic matter in the orchard and elsewhere. It can contaminate peaches or other stone fruits during harvesting and packing. *A. niger* grows most rapidly at high temperatures, the optimum being between 86° and 98° F. Little or no growth occurs below 45° or above 113°. Spores will be killed at 131° for

30 minutes. Normally the organism does not attack uninjured, freshly harvested peaches unless they are overripe. Losses from black rot usually occur on injured fruit or fruit subjected to prolonged storage at low temperature before ripening at high temperature.

Control measures

Losses from black mold rot can be reduced by careful handling to avoid injury to the fruit, avoiding excessive long storage periods, and using sanitary measures in packinghouses and in wholesale and retail markets.

(See 160, 186.)

Blue Mold Rot

Pencillium sp.

Occurrence and symptoms

Blue mold rot usually does not occur on freshly harvested, uninjured peaches, nectarines, or apricots. The rot commonly is found, however, on injured or overripe fruit or fruit that has been stored at low temperatures for long periods.

The first symptoms of blue mold rot on these fruit are small tan spots occurring anywhere on the surface. The skin over the spots is moist and readily breaks or slips from the fruit. Beneath the spot the flesh is tan and moist, but fairly firm. With slight pressure, the infected tissue can be scooped out, leaving a saucerlike depression up to $\frac{1}{4}$ to $\frac{1}{2}$ inch deep and surrounded by healthy tissue. As the spot enlarges, white tufted cushions of mold appear near the center, which later produce masses of powdery, blue-green spores. The sporulating areas often are surrounded by a white vegetative growth of the fungus. The affected areas gradually enlarge, but rarely involve the whole fruit (pl. 3, *E* and *F*).

Causal factors

See Cherries, page 4.

Control measures

See Cherries, page 4.

Peaches and nectarines are not as tolerant of atmospheres with high CO₂ levels as cherries, nor are they as subject to blue mold rot as cherries. Consequently, atmospheres with high CO₂ levels generally are not used in commercial shipments of peaches and nectarines. Controlled atmosphere storage of these fruit at 32° F. with

1 percent oxygen and 5 percent CO₂ has reduced physiological disorders greatly, but has reduced decay only slightly.

(See 10, 160, 186.)

Brown Rot

Monilinia fructicola (Wint.) Honey and *M. laxa*

(Aderh. & Ruhl.) Honey

Occurrence

Throughout the world brown rot is the most important disease of peaches, nectarines, and apricots. In the United States the disease occurs wherever these fruits are grown, but consistently causes the greatest losses to peaches grown in the Southeast.

Brown rot develops on peaches in the orchard, in packinghouses, during transit, during marketing, and in the homes of consumers. The rot develops on freshly picked fruit, as well as on fruit after long transit or storage periods. It will develop on relatively immature fruit nearly as fast as on mature fruit. No commercial varieties of peaches, nectarines, or apricots are resistant to this disease. The J. H. Hale and Red Top peach and most nectarines are particularly susceptible to brown rot. Most canning cling peaches and early soft flesh peaches are highly susceptible.

The development of brown rot during marketing of these fruits is correlated closely with weather conditions at the time of harvest. Rainy periods stimulate spore production on infected twigs or mummies, and if fruit is maturing during this period, infection in the orchard may be severe. When high humidity follows rainy periods, spore production continues for long periods. In dry periods, even though the relative humidity may be high, spore production is limited and late-season infection in the orchard is slight.

Symptoms

The earliest symptoms of brown rot are small, water-soaked spots on the surface of fruits. Beneath these spots, the flesh also is water soaked to glassy, the discoloration extending about $\frac{1}{8}$ inch. Within 24 hours, the skin and affected flesh become brown to black. At 60° to 80° F. these spots enlarge rapidly, usually remain circular and nonsunken, and are covered with a tough, leathery skin that, even with moderate pressure, remains intact over the decayed flesh. The flesh becomes brown and somewhat watery, but firm, the decay often extending to the pit of the fruit.

In advanced stages, tan-gray, powdery spore masses, often in concentric rings, cover the surface of affected areas. Within 3 to 4 days at room temperature, the entire fruit may be decayed, but with the skin remaining intact. Later these fruit shrivel and become mummies.

Brown rot spreads rapidly from diseased to healthy fruit in shipping containers. Severe "nesting" usually occurs when heavily infected fruits are packed and held at moderate temperatures (pl. 2, C and D; pl. 6, A, B, and C).

Causal factors

Two species of *Monilinia*, *M. fructicola* and *M. laxa*, produce brown rot of stone fruits. In the United States, *M. laxa* is found mainly in California, whereas *M. fructicola* is found throughout the country.

These fungi overwinter chiefly on mummies that remain on trees or that have fallen to the ground. Sometimes the brown rot fungi overwinter on twig and limb cankers. During rainy periods in the spring, spores are disseminated from these sources and infect peach blossoms, causing additional twig infections. Young fruits may become infected by spores from these twigs; the infection may remain latent until the fruits mature. Additional infections may occur during rainy periods later in the season when the fruits are maturing. The brown rot organism can penetrate the unbroken skin of the fruits, but insect injuries, hail injury, wind whipping, and bruising greatly increase infection.

Fruits also may become infected in packinghouses or markets when in contact with contaminated belts, tables, or boxes. Hydro-coolers, in almost universal use in the Eastern and Southeastern United States, can be one of the principal methods of spreading brown rot. If the water in these coolers is not changed frequently or treated with a fungicide, a large population of *Monilinia* spores may contaminate the water and infect fruit passing through the cooler.

Spores of *M. fructicola* can germinate and grow at temperatures from 32° to 90° F. For rapid growth of this organism and for spore production, temperatures from 60° to 80° are ideal. Most of the spores are killed when exposed to 120° water for 3 minutes or to 125° water for 1 minute. Exposure to 130° air with 90-percent relative humidity for 1 hour also killed the spores, but exposure to air with only 50-percent relative humidity did not kill the spores. Dipping fruit in 125° water for 2 to 3 minutes has effectively killed spores on the surface.

Germination of *Monilinia* spores requires the presence of free water. Rainy periods, therefore, will result in severe orchard infections, especially when fruit are nearly mature. High humidity following the rainy period will prolong the infection period. However, high humidity alone does not provide sufficient moisture to seriously increase the development and spread of this decay.

Control measures

Primary control of brown rot should begin with sanitation practices in the orchard, in the packinghouse, and on the market. Destroying or burying mummified fruits in the orchard, cleaning grading and packing equipment, keeping the water clean in hydro-coolers, and destroying cull piles of fruit around orchards and packinghouses will reduce the population of brown rot spores and hence reduce the possibility of fruit infection. Control measures also should include applying insecticides for flies and gnats at packinghouses and markets since these insects carry *Monilinia* spores from diseased to healthy fruit.

Proper orchard spray schedules are necessary to control brown rot in orchards. For details, the U.S. Department of Agriculture or State agricultural colleges should be consulted.

Refrigeration is the most commonly used method of controlling brown rot after harvest. Temperature studies have shown that as much brown rot develops in peaches held 1 day at 75° F. as in 3 days at 50°, 7 days at 41°, or 25 days at 32°. Prompt cooling of fruit to temperatures below 40° will reduce the growth and spread of this organism. Hydrocooling is a rapid method of removing field heat. Maintaining transit temperatures below 40° will slow the development of brown rot, though further development will occur when fruit is moved to moderate marketing temperatures.

Postharvest fungicide treatments, such as chlorine in the hydro-cooling water, have been effective in reducing populations of *Monilinia* spores on the surface of peaches, but have not controlled the growth of organisms that have already infected fruit in the orchard. Heat treatments have been effective in controlling incipient infections of peaches and nectarines. Dipping the fruit in 125° to 128° F. water for 2 to 2½ minutes destroys *Monilinia* spores on the fruit and also prevents the development of organisms already established under the skin.

(See 8, 9, 11, 12, 22, 29, 30, 31, 33, 46, 47, 48, 59, 76, 83, 89, 90, 91, 98, 99, 100, 103, 115, 120, 127, 130, 132, 139, 156, 157, 158, 161, 166, 170, 176, 177, 180, 196, 202, 205.)

Cladosporium Rot

Cladosporium herbarum Lk. ex Fr.

Occurrence and symptoms

Cladosporium rot rarely occurs on peaches, nectarines, or apricots. Fruits subject to long storage or transit periods sometimes suffer from this disease.

Cladosporium rot usually affects only a small area of the fruit, such as the tissue lining a wound or skin break. A thin, fluffy, white growth of mold usually covers the affected area. In late stages the surface of the decay turns yellowish olive as spores of the fungus are produced. On peaches the spots usually are less than 1 inch in diameter. The most striking feature of the decay is a hard, cone-shaped, gray to black core extending deep into the flesh. The core is surrounded by moist, brown tissue from which it is easily separated.

Causal factors and control measures

See Cherries, page 6.

(See 160.)

Coryneum Blight

Coryneum carpophilum (Lev.) Jauch.

Occurrence

Coryneum blight was first recorded in France in 1853 and occurs on peaches, nectarines, and apricots in most countries of Europe, in Algeria, in Australia, and in New Zealand. In the United States, the disease is most serious in the Pacific Northwest, but also causes damage to stone fruits grown in California, Colorado, Indiana, Michigan, New York, Ohio, and Utah. Coryneum blight also is known as peach blight, winter blight, pustular spot, and shot hole. The disease primarily affects twigs, dormant buds, leaves, and blossoms on peaches and nectarines, but sometimes damages the fruit. On apricots, the disease more frequently attacks the fruit. Diseased fruits are usually culled in the packinghouse, but occasionally reach the market.

Symptoms

On the fruit, coryneum blight causes small, purplish-red, circular spots that usually are distinct from one another. The spots may enlarge to $\frac{1}{8}$ or $\frac{1}{4}$ inch in diameter, a cream-colored area develops in the center, and the margins become dark red to brown.

Later the spots are slightly sunken and colored rusty brown. Small cracks sometimes develop in affected areas, and gumming occurs (pl. 2, *B*; pl. 4, *E* and *F*).

Causal factors

The causal fungus, *Corynyneum carpophilum*, infects buds and twigs during moist weather in the fall and winter. Blossoms and young fruit may become infected during the warm, rainy spring weather. The spores are dispersed by rain or splashing water. Infection occurs when susceptible parts of the hosts are wet for several hours. The optimum temperature for decay development and growth of the fungus is near 70° F. Decay development is somewhat slower at 80° than 70°, and at 40° decay development is delayed for 15 to 20 days. Spores of the fungus can germinate at 40° and incipient infections may occur. Decay resulting from these infections develops very rapidly when fruits are transferred to higher temperatures.

Coryneum blight does not spread from diseased to sound fruit after harvest, although there is some indication that individual spots may enlarge. Spots $\frac{1}{2}$ inch or more in diameter and sunken $\frac{1}{8}$ to $\frac{1}{4}$ inch below the margins have been observed on the market. Such spots are considerably larger than those commonly found at harvest.

Control measures

Control of coryneum blight depends upon proper applications of chemical sprays in the orchard. After harvest, decay development may be delayed by storing and shipping the fruits at temperatures below 40° F.

(See 40, 62, 83, 87, 136, 160, 173, 174, 203, 204, 209.)

Diplodia Rot

Diplodia natalensis P. Evans

Occurrence

Diplodia rot first was observed on peaches in Georgia in 1950. The disease has been found since on peaches grown in several other States on the east coast. Diplodia rot is found most commonly on mature-ripe fruit, but also may develop during ripening of previously stored green fruit. Although the rot is not of great economic importance, the potential loss is important since diplodia rot develops rapidly at the temperatures at which peaches normally are ripened.

Symptoms

In its early stages, diplodia rot may be mistaken for either brown rot or rhizopus rot. The small, light-brown spots caused by *Diplodia* enlarge rapidly at moderate temperatures and may cover most of the peach. The skin over affected areas is somewhat softer than that of peaches with brown rot, but more tenacious than that of fruit with rhizopus rot. The decayed flesh is tan to brown, is somewhat watery, and sometimes has a sour odor. The decay gradually extends to the pit and eventually causes the whole fruit to shrivel or mummify. Surface growth of the mold over affected areas is profuse, fine, and cottony white. Later, gray to black fruiting bodies appear over the surface of fruit in advanced stages of decay (pl. 4, C).

Causal factors

Rot caused by *Diplodia natalensis* develops after fruits are harvested and is more prevalent on mature ripe than on immature green peaches. The initial infection may occur at an injury, but the decay will spread by contact from decayed to sound fruit, sometimes involving all the fruit in a box. On mature fruit the decay develops most rapidly at 80° to 90° F. and at high relative humidity. The maximum temperature for growth of the causal fungus is 102° and the minimum is 45° and 50°.

Similar diseases of peach caused by *Diplodina persicae* (Horne and Hawthorne) and *Phomopsis persicae* (Sacc.) Smith and Ramsey have been reported from Louisiana and South Carolina.

Control measures

Specific control measures have not been developed for this disease, but obvious ones would include refrigeration below 45° F., careful handling to reduce injuries, packinghouse sanitation, and restricting the length of the storage period for fruit from orchards known to harbor the *Diplodia* fungus.

(See 94, 95, 171, 172, 207, 208.)

Gray Mold Rot

Botrytis cinerea Pers. ex Fr.

Occurrence and symptoms

Gray mold rot rarely occurs on freshly harvested and marketed peaches, nectarines, or apricots, but does occur on these fruits if storage or transit periods have been excessively long. Fruits that

have been injured are subject to gray mold rot earlier in the post-harvest period.

The first symptoms of gray mold are light-colored spots that may occur anywhere on the fruit. The surface of the spot turns tan, becomes slightly wrinkled, and is a lighter tan near the margins. The skin over the decayed area slips readily from the underlying tissue when a slight pressure is applied. As the spot enlarges, a white to gray growth of the mold appears. Later large numbers of gray-brown spores are produced. The decayed flesh is brown, soft to mushy, and watery (pl. 2, *E* and *F*; pl. 3, *A*, *B*, and *C*).

Causal factors and control measures

See Cherries, pages 7 and 8.
(See 160.)

Leaf Curl

Taphrina deformans (Berk.) Tul.

Occurrence

Leaf curl occurs wherever peaches and nectarines are grown, even though it is easily controlled by proper orchard treatments. Apricots are immune to leaf curl. On peaches and nectarines the disease originates in the orchard where the leaves may be severely damaged, often resulting in almost complete defoliation of the trees and great reductions in yield. Sometimes the fruits are affected, but these usually are culled at the packinghouse and seldom reach the market. In some peach-growing areas losses may range up to 15 percent of the crop in addition to indirect losses caused by defoliation.

Symptoms

Symptoms of leaf curl on fruits are red blotches that may occur anywhere on the surface. Sometimes depressed, reddish, lacy markings occur on the skin. Large, partly red, wartlike protuberances may develop in the red blotches, or overgrowths occur, causing the fruits to be misshapen. In severely affected fruit, deep cracks may develop.

Causal factors

Spores of *Taphrina deformans*, the fungus causing leaf curl, survive during the summer, fall, and winter on the surface of tree branches or on the ground. In the spring, the spores germinate and infect young leaf and flower buds. When young fruit become

infected, they usually fall from the tree. Maturing fruit may be attacked when proper weather conditions exist. The organism can grow at temperatures below 50° F. and up to about 86°, but optimum growth is at 68°. The actively growing fungus is killed at 115°, but when dried or dormant, it will withstand temperatures up to 203°. The disease is favored by cold, wet, spring weather and usually is of minor importance in drier areas of the Western United States.

Control measures

Control of leaf curl depends on spraying with a fungicide before any vulnerable tissue is exposed in the spring. One application of a suitable fungicide at the correct time is all that is necessary.

(See 8, 83, 87, 104, 126, 128, 129, 140, 160, 186.)

Powdery Mildew

Sphaerotheca pannosa (Wallr. ex Fr.) Lev. var.
persicae Woron.

Occurrence

Powdery mildew occurs on peaches, nectarines, and apricots, affecting primarily leaves and fruit in the orchard. The disease is widespread over most areas where these fruit are produced. The Rio Oso Gem peach variety is particularly susceptible to powdery mildew. In California, powdery mildew of apricots has been correlated with the distance of the orchards from infected rose plantings. The disease is relatively unimportant as a marketing disease because most affected fruit is discarded at the packing-house, but serious losses sometimes occur when marred fruit may be rejected both for fresh market and for canning.

Symptoms

Symptoms of powdery mildew on apricot fruit first appear in late spring or early summer when the fruits are small and green. Light-green spots covered with a whitish growth of mold may occur over much of the fruit surface. As the fruit develops, it may become flattened on the affected side. The spots become dark brown with dead surface tissue, giving the fruit a dirty appearance.

On peaches and nectarines the fungus forms small, white, circular spots on the surface of the fruit. These spots may enlarge until they cover most or all of the fruit. Such fruit turns reddish or pinkish at first and then a dead brown. The underlying flesh is

rather hard, with a dark, water-soaked appearance. The affected tissue may extend to the pit (pl. 5, *E* and *F*).

Causal factors and control measures

The causal fungus, *Sphaerotheca pannosa* var. *persicae*, is an obligate parasite, growing only on living tissues of the host plant. Spores of the fungus infect the fruit early in the season, and after germinating on the surface are able to penetrate uninjured tissue. The disease can develop in relatively hot, dry weather, though some moisture is needed for spore germination.

On eastern fruits, powdery mildew was not a serious problem until organic chemical sprays replaced sulfur sprays. The disease can be controlled very effectively with sulfur or with organic chemical sprays containing a small amount of sulfur.

(See 8, 160, 210.)

Rhizopus Rot

Rhizopus stolonifer (Ehr. ex Fr.) Vuill.

Occurrence

Rhizopus rot is second only to brown rot as the most important market disease of peaches, nectarines, and apricots. In some areas rhizopus rot is the only important market disease of these fruit. Although the disease sometimes occurs in the orchard, it is found more commonly after the fruit is harvested. Rhizopus rot develops slowly on immature fruits, but develops rapidly when the fruits mature and ripen. The disease also develops rapidly when fruits with long refrigerated storage or transit periods are transferred to ripening temperatures.

Symptoms

The *Rhizopus* fungus usually enters the fruit at an injury or bruise. The first symptom of the disease is a circular, tan area surrounding an island of apparently healthy skin. Within a few hours, all the skin in the affected area becomes tan to brown. A slight pressure applied to the surface causes the skin to slip from the flesh. As the decay progresses, a fluffy, white growth of mold appears near the center and rapidly covers the affected area. White, spherical, spore-producing bodies develop almost immediately, and within 24 hours from the time mold growth first appeared, the white fruiting bodies turn jet black. Finally, the mold

growth turns gray and multitudes of black spores are produced. The rot develops rapidly at ripening temperatures, spreading over an entire fruit within 48 hours, and from diseased to healthy fruits, frequently spoiling all the fruit in a box.

The flesh in affected areas is tan, somewhat mushy, and watery. In advanced stages, the decay extends to the pit and, with pressure from adjoining fruit, causes the whole fruit to collapse (pl. 2, *G* and *H*; pl. 6, *D*, *E*, and *F*).

Causal factors

Rhizopus stolonifer usually infects fruit after harvest, while in field containers, or during packing, grading, hydrocooling, transport, or distribution. Cuts, cracks, or bruises resulting from rough handling of the fruit form ideal entrance points for the organism.

The critical temperature for rhizopus rot is 45° F. The fungus will not grow nor the spores germinate below 45°. Optimum spore germination is at 70° to 80° and the maximum slightly above 90°. Other forms of *Rhizopus* will germinate and grow above 100°. In water at 120° or 130°, *Rhizopus* spores are killed in 2 to 3 minutes.

Control measures

Sensitivity of the causal organism to low temperature makes good precooling and refrigeration in storage and transit a primary control measure. Temperature studies have shown that as much rhizopus rot develops in peaches held 1 day at 85° F. as in 3 days at 59°, or 10 days at 50°. The fact that infections occur primarily through wounds makes careful handling to avoid injuries another important method of reducing losses from this disease. Sanitation at all stages of handling is important. Heat treating peaches and nectarines in 125° to 128° F. water for 2 to 3 minutes has proved an effective method not only for controlling *Rhizopus* spores on the surface of peaches and nectarines, but also for controlling incipient infections of the fruit.

(See 6, 29, 30, 31, 81, 115, 176, 177, 179, 180, 198, 202.)

Ring Pox

Ring pox is a virus disease affecting apricots in southern California, western Colorado, and central Washington. It is indigenous to the areas where it has been found and apparently does not

spread rapidly to other areas. Apricot ring pox has not been found outside the United States. Infected apricot trees may be ruined by the disease, but the virus produces no symptoms on peaches. Fortunately the disease is not widespread, which limits its economic importance.

Symptoms of ring pox on apricot fruit do not appear until the pit starts to harden, and some fruits appear normal until 2 to 3 weeks before they mature. The first symptoms are water-soaked grey spots and rings on the skin and just under the skin. As the fruit matures, the discolored areas become reddish purple and slightly raised and bumpy. The spots turn brown to reddish brown and several spots may run together and form irregular blotches over the surface of the fruit. The brown tissue later may crack and fall out, and when the fruit softens, the brown areas may extend deeper into the flesh, but never to the pit.

Control of ring pox lies in the selection of disease-free nursery stock and destruction of diseased trees in the orchard.

(See 21, 45.)

Rust

Tranzschelia discolor (Fckl.) Tranz. & Litv.

Rust is rarely found on peaches in the market. Usually the disease is of minor importance, but in some years it may become epidemic in certain areas. Rust of stone fruits is found in the Southern and Pacific Coast States. It is primarily a foliage and bark disease, but occasionally affects the fruit.

Fruit infections occur when the fruit nears maturity. The first symptoms of rust on peach are water-soaked, dark-green spots, $\frac{1}{4}$ to $\frac{1}{8}$ inch in diameter, which become sunken as the fruit enlarges. The center of the spot is a darker green than the margin and later turns deep yellow or orange. The fungus may produce fruiting bodies in the center of the spots, which appear as dark-brown, dusty areas. The tissue beneath the spots is tough and leathery and clings tightly to adjacent healthy tissue. This characteristic makes affected fruit difficult to peel, and the resulting blemishes preclude using the fruit for processing.

Rust infections occur only in the field and the disease does not spread during the postharvest period. Affected fruits should be culled in the packinghouse, but a few occasionally reach the market.

(See 8, 57, 74, 166, 185.)

Scab

Cladosporium carpophilum Thuem.

Occurrence

Scab occurs in all of the peach-growing areas of the United States, except Oregon and Washington. Normally the disease is more serious in States east of the Rocky Mountains than in the Western States. Nectarines and apricots are affected less seriously than peaches. Since scab originates in the orchard, most affected fruit should be eliminated in packinghouses before shipment. However, some peaches with scab appear on the market. The disease can cause serious economic losses in the orchard, but is of minor importance as a market disease. Scab sometimes is called freckles or black spot.

Symptoms

Symptoms of scab on peach fruit first appear when the peaches are about half formed. Early symptoms are circular, olive-green spots about $1/16$ to $1/8$ inch in diameter, which may occur singly or in groups. The spots have rather poorly defined borders at first, but later the margins become distinct. Scab occurs primarily on the stem end or exposed sides of the fruit, but may occur anywhere on the skin. The spots enlarge slowly, coalesce, and turn dark olive or black, due to the myriads of black spores that are produced. A layer of cork develops below the spots, and as the fruit develops, it becomes misshapen. Severely scabbed peaches may crack open, sometimes as far as the pit, thus exposing the fruit to attack by other decay fungi. Affected fruit usually does not attain normal size (pl. 5, *C* and *D*).

Causal factors

Scab is caused by *Cladosporium carpophilum*. The fungus overwinters on the twigs and produces spores that infect the young fruit in the spring or early summer. The spores are produced in greatest abundance in wet weather and at moderate temperature (65° to 75° F.) and are disseminated by splashing rains. Symptoms of the disease on the fruit may not be expressed until 1 to 2 months after infection has occurred. Scab is usually more serious in orchards lying in low, moist areas than in areas with good air drainage.

Control measures

Scab can be controlled readily by one orchard application of a fungicide shortly after petal fall. The disease does not develop or spread in transit or storage.

(See 8, 60, 83, 87, 101, 157.)

Sour Rot

Geotrichum candidum Lk. ex Pers.

Occurrence and symptoms

Sour rot of peaches has been found in midwestern markets on fruit from Georgia, New Jersey, North Carolina, and Pennsylvania. In midsummer, about 3 percent of the peaches inspected had sour rot. The disease is usually associated with bruising or cutting of the fruit and is particularly prevalent in fruit with split pits. Sour rot generally affects only ripe fruit, but also may affect severely bruised green fruit.

External symptoms of sour rot are depressed, dark-brown areas with purple margins. Later, white masses of spores are produced on the surface of affected areas. Internally, the rotted flesh is wet, soft, and dark brown, and occasionally has cavities filled with masses of white spores. The rot may extend to the pit. Fruit with split pits affected by sour rot may not have external symptoms of the disease, but when cut, the rot is apparent in tissue surrounding the pit. Sour rot has a characteristic vinegary odor (pl. 4, D).

Causal factors and control measures

The fungus, *Geotrichum candidum*, is widespread, growing on many kinds of fruit, vegetables, and organic matter. Spores of the fungus may be spread by vinegar flies from decayed fruit to cracks or bruises in healthy fruit. The spores may also be spread in picking boxes and handling equipment.

The minimum temperature for spore germination, growth, and infection by the fungus is about 36° F., the optimum 86°, and the maximum 101°. At about 60°, the rot spreads very rapidly in ripe peaches.

Control of sour rot lies in careful handling to reduce bruising, culling to remove injured or infected fruits that would provide sources of inoculum, and good sanitary practices during picking

and packing. Rapid cooling of the fruit and refrigeration at low temperature will reduce losses from sour rot.

(See 38, 39, 145.)

Plums

Alternaria Rot (Green Mold Rot)

Alternaria sp.

Occurrence and symptoms

Alternaria or green mold rot is occasionally seen in eastern markets on plums and fresh prunes shipped from California, Idaho, Michigan, and Oregon. A spotting of the fruit, caused by *Alternaria* sp., has been noted in Canada. The decay occurs in nicks, cuts, or bruises and in fruit weakened by prolonged storage. Only small areas are involved, but the decay detracts from the appearance of the fruit.

Alternaria rot appears as a firm, dark-brown to black spot. The decay is shallow in its early stages, but later may progress to the pit, forming a cone of diseased tissue. The affected tissue is firm and can be separated easily from the healthy tissue, the boundaries of the decay being sharply delineated. In late stages the decayed area is usually covered with olive-green spores of the fungus, but sometimes a white vegetative growth of mold may hide the green spores (pl. 7, A).

Causal factors

Green mold rot of plums is caused by one or more species of *Alternaria*, which usually enter the fruit through breaks in the skin. Growth of this mold is most rapid at 85° F., but decay will develop slowly at transit temperatures near 40°. Other types of decay may follow *alternaria* rot. The decay is easily confused with *cladosporium* rot, although the latter develops somewhat more slowly than *alternaria* rot. Viewing the spores with a microscope is necessary for positive identification of the rot.

Control measures

Since the causal organism is frequently associated with cuts and bruises, careful handling to reduce these injuries during harvesting, packing, and shipping will reduce *alternaria* rot. Quickly precooling plums to the recommended storage temperature of 31°

to 32° F. will slow the development of rot and reduce the chance of new infections.

(See 41, 51, 112, 160.)

Bacterial Spot

Xanthomonas pruni (E. F. Sm.) Dows.

Occurrence and symptoms

Bacterial spot of plums is found occasionally in orchards along the east coast of the United States and in the North-Central and Midwestern States. Bacterial spot is also known as black spot of plum. The disease appears as leaf spots, shotholes, cankers on twigs, and infrequently as spotted and somewhat deformed fruit. American and European plum varieties are less susceptible than Japanese varieties, Kelsey and Gaviota.

On the fruit, the disease first appears as small, light-brown to red spots. In advanced stages the spots become depressed, enlarged, and darker, and may coalesce. A callus may form as a response to the disease while the fruit is growing; and when young fruit are infected, cracks may appear within the depressed area because of the growth strains involved. When fully grown fruit become infected, cracks do not develop. A gummy exudate of the bacteria may ooze out of affected areas.

Causal factors and control measures

See Peaches, Nectarines, and Apricots, pages 11 and 12.

(See 56, 58, 109, 153, 159, 184.)

Blue Mold Rot

Pencillium sp.

Occurrence and symptoms

Blue mold rot is one of the most common rots affecting plums during storage, transit, and marketing. The disease rarely occurs in the field, where it affects only mature fruit.

On the market, the rot is associated with cuts, cracks, or other injury to the fruit. In its early stages, the rot appears as a bleached or light-brown, circular, fairly soft spot with a definite outline. Later the skin cracks and white tufts of the fungus appear. The tufts at the center of decay turn bluish green as the spores are produced, whereas the newer tufts around the rim of the decay are still white. The decayed flesh is wedge or saucer shaped, water soaked, or discolored brown. In advanced stages,

the decay may encompass the whole plum. Fruits with blue mold have a musty odor and taste (pl. 7, *B*).

Causal factors

See Cherries, page 4.

Control measures

Careful handling of plums to prevent skin breaks and bruises during harvesting, storing, packing, and shipping will reduce the incidence of blue mold. Excessively tight packs cause bruises that favor decay. Rapidly precooling the fruit to temperatures between 40° and 45° F. effectively slows the development of blue mold in fruit of average maturity. Very mature fruit should be precooled to temperatures between 35° and 40°.

Plums usually are not stored longer than a few weeks because of their perishability. Prolonged storage at low temperatures (31° to 32° F.) predisposes the fruit to blue mold rot.

The use of modified atmospheres during cold storage slows the ripening of some varieties of plum, thereby reducing susceptibility to decay. A 7 to 11 percent CO₂ level in the atmosphere reduces ripening rates and decay of Nubiana and El Dorado plums. However, plum varieties differ greatly in their responses to modified atmospheres; thus, each should be tested carefully before this procedure is used on large quantities of fruit.

(See 19, 41, 49, 50, 152, 160, 189, 202.)

Brown Rot

Monilinia fructicola (Wint.) Honey and *M. laxa*
(Aderh. & Ruhl.) Honey

Occurrence

Brown rot usually is not as serious on plums and prunes as on other kinds of stone fruit. However, considerable losses sometimes occur in the eastern part of the United States and the disease also has caused losses in shipments from California, Idaho, Oregon, and Washington. In the West, the disease is more prevalent in varieties that mature late in the season than in early varieties. Susceptibility to infection increases as the fruit approaches maturity.

Japanese and American varieties of plums appear less susceptible than European varieties. No variety of plum is immune to brown rot. Greatest losses are in those varieties in which the plums grow in clusters since the fungus spreads rapidly from one decayed fruit to others in contact with it.

Symptoms

In light-colored plum varieties, brown rot first appears as a firm brown spot that enlarges rapidly. The flesh softens as the decay progresses. In dark plum varieties, the discoloration of affected areas is not readily discernible at first. As the decay progresses, the intact skin becomes leathery and dark brown or black. Ashy-colored tufts of the fungus and masses of tan spores often occur on discolored areas. Eventually the fruit shrivels and mummifies (pl. 7, C).

Causal factors and control measures

See Peaches, Nectarines, and Apricots, pages 15 and 16.
(See 46, 64, 65, 89, 93, 96, 103, 152, 156, 163, 165.)

Cladosporium Rot

Cladosporium herbarum Lk. ex Fr.

Occurrence and symptoms

Cladosporium rot, also called green mold rot, is frequently found on plums and fresh prunes shipped to eastern markets from California, Idaho, Oregon, and Washington. The disease is particularly prevalent in fruit held for prolonged storage and transit periods.

Usually the decayed areas are small and are associated with nicks, cuts, bruises, or other injuries. In the early stages the decayed spots are shallow and may be overlaid with a white fungal growth that later produces olive-green spores. The decay may later extend from the surface to the pit, forming a dark, usually cone-shaped mass of tissue, which can easily be separated from the healthy part of the fruit (pl. 7, D).

Causal factors and control measures

See Cherries, page 6.
(See 16, 26, 160.)

Coryneum Blight

Coryneum carpophilum (Lev.) Jauch.

Occurrence and symptoms

Coryneum blight of plums has been reported from California to Idaho and Washington and also from foreign countries. The disease is of field origin and is seldom seen on fruit in the market, especially in the Eastern United States. The European plum varieties are more susceptible to coryneum blight than the Japan-

ese varieties. The disease is also known as shothole, winter blight, brown spot, and pustular spot. The same organism is one cause of the European piercing blight.

Symptoms of the disease on the fruit are small red or purple-red spots, which gradually enlarge, become depressed, and turn brown. The centers of the spots remain light in color because of the formation of dry, corky tissue.

Causal factors and control measures

See Peaches, Nectarines, and Apricots, page 18.

(See 107, 160, 174, 203, 204.)

Gray Mold Rot

Botrytis cinerea Pers. ex Fr.

Occurrence

Gray mold occasionally attacks plums in storage and on the market. It is most prevalent on varieties that are harvested late in the season and that are exposed to high moisture conditions before picking. Highly mature fruit is more susceptible to gray mold rot than less mature fruit.

Infections of plums usually occur through cracks and wounds, but may also occur by contact when the mold grows from diseased to adjacent sound fruit, forming "nests" of decayed fruits. In California, infections of green fruits have been observed, the fungus gaining entrance by first infecting adhering flower parts. In very wet spring weather the *Botrytis* fungus causes blossom blight of plums.

Symptoms

In its early stages, gray mold rot is characterized by a light-brown, firm spot with a distinct boundary. In dark plum varieties there is a slight fading of the skin color, rather than browning observed in light varieties. In advanced stages of gray mold rot, the spot becomes dark brown or almost black and may become leathery. Internally, the tissues are either water soaked or discolored brown. The affected area becomes covered with a white, fluffy growth of mold and grayish spore masses. These may be scanty or abundant, depending upon prevailing humidity and temperature. The decay is softer than brown rot, but not as soft as blue mold or rhizopus rots. Decayed areas are shallow at first, but later may extend to the pit. Gray mold has a very slight earthy odor (pl. 7, E).

Causal factors and control measures

See Cherries, pages 7 and 8.

(See 41, 112, 131.)

Rhizopus Rot

Rhizopus stolonifer (Ehr. ex Fr.) Vuill.

Occurrence and symptoms

Rhizopus rot is an important disease of plums in transit and in marketing channels. Various surveys have indicated that, over a period of years, about 1 percent of the plums and prunes reaching eastern markets are affected with rhizopus rot. Very ripe plums are more subject to decay than less ripe fruit.

Rhizopus rot first appears as tan to brown spots on the skin. Within a day at room temperature, affected areas are covered by the white, coarse, stringy growth of mold. Small spore-bearing heads are produced by the mold, which are white at first but later turn gray or black. The mold forms nests, rapidly spreading from one fruit to another. In the early stages, the flesh is water soaked and separates readily from the skin. Later the affected flesh darkens and the cell walls break down, releasing juice when the slightest pressure is applied. This condition is known as "leak" and frequently results in the staining of containers or other objects in contact with the fruit. The decay has a fermented odor (pl. 7, F).

Causal Factors

See Peaches, Nectarines, and Apricots, page 23.

Control Measures

The best postharvest control for rhizopus rot is good refrigeration. The causal organism does not grow at temperatures below 45° F. Precooling plums promptly to this temperature and shipping them at temperatures between 35° and 45° will greatly reduce the development of rhizopus rot. Most plum varieties are not adapted to long storage periods so should be marketed promptly.

See Peaches, Nectarines, and Apricots, page 23.

(See 5, 17, 29, 30, 41, 120, 179, 202.)

Rust

Tranzschelia discolor (Fekl.) Tranz. & Litv.

The rust disease of plums is usually of little economic importance and is rarely seen on fruit in the market. Most Japanese and all American varieties may be attacked, although Japanese

varieties are less susceptible. The disease has been reported on plums grown in California.

The causal organism, *Tranzschelia discolor*, affects mostly leaves, causing premature defoliation. Rusty pustules surrounded by corky, suberized areas may occasionally develop on the fruit.

The spread of rust in the orchard is favored by rainfall and high humidity. Postharvest applications with sulfur are effective against this fungus. Recommendations of local authorities on control methods should be followed.

See Peaches, Nectarines, and Apricots, page 24.

(See 8, 57, 169, 185.)

Scab

Cladosporium carpophilum Thuem.

Occurrence and symptoms

Scab, also known as freckles or black spot, is of orchard origin and does not spread in storage or in transit. The causal fungus is widespread, although more serious east of the Rocky Mountains than in the Western United States. Scab on freshly shipped plums is occasionally seen during marketing. The poor external appearance of the affected fruit lowers the marketing grade.

The first symptoms of scab are small, circular, yellow spots on the skin of the fruit. A shallow layer of cells underlying the spot also turns yellow. Later a brown corky area appears in the center of the spot. As the spots enlarge, they may coalesce and turn dark olive or black as the fungus spores develop. Cracks often develop in the diseased areas, providing entry ports to the organisms causing brown rot, rhizopus rot, and blue mold rot.

Causal factors and control measures

See Peaches, Nectarines, and Apricots, pages 25 and 26.

(See 13, 14, 28, 143.)

NONPARASITIC DISEASES OF STONE FRUITS

Orchard- and Weather-Related Disorders

Cracking

Cracking among the stone fruits is most common in cherries, although plums and peaches occasionally suffer from the disorder. Estimates indicate that an average of 15 to 20 percent of the sweet cherries in Michigan crack and that losses in California, Michigan, Oregon, Utah, Washington, and other States where cherries are grown often amount to \$6 million annually. Most cracking occurs

in the orchard when fruit is exposed to rain or high humidity shortly before harvest. Cherries absorb moisture through the skin and also from the tree; the moisture may be translocated from both roots and foliage. More cracking occurs at high temperature (85° F.) than at low temperature (40°), and cracking increases as the sugar content of the fruit increases from 17 percent up to 20 to 21 percent; at higher sugar contents, cracking decreases. The Bing cherry variety is particularly susceptible to cracking; Black Tartarian, Lambert, Napoleon, Schmidt, and Windsor crack less than Bing; and Montmorency cracks less than any of the sweet varieties. The toughness or elasticity of the skin is a factor in determining susceptibility of various varieties to cracking.

Cherries crack first in surface areas having the greatest curvature. Cracks may be in the form of deep crescent or V-shaped breaks in the skin near the apex of the fruit, deep, straight slits along the sides of the fruit, or circles or semicircles in the stem cavity. The tissue lining the cracks usually dries out and may heal over. However, the cracked fruit often become infected with decay-causing fungi (pl. 8, B).

Fresh Italian or French prunes sometimes split or crack along the sides or on the ends, usually just before ripening. Or growth cracks may develop in fruits that have been injured at an early stage of development by insects; later expansion in the size of the fruit causes the skin to rupture in the injured areas.

Both peaches and plums sometimes crack as a result of renewed growth when rainfall follows periods of dry weather (pl. 8, A). A defect called open suture affects Stanley plums in Idaho and appears to result from growth stresses along all or a part of the suture. Late Santa Rosa plums tend to crack at the suture because this part of the fruit ripens first. Nubiana plum is prone to cracking at various places on the surface. Peaches sometimes crack when there is an excess of boron in the soil.

Cracking of cherries and some other stone fruits is favored by rainfall, the presence of free moisture on fruit and foliage, and high humidity. Helicopters have been used to dry off the trees and various cultural practices have been used to increase the transpiration rate of the trees, thereby reducing the turgor of the fruit. Certain orchard sprays have been effective in increasing the resistance of cherries and prunes to cracking. Most cracked fruits are removed in the packinghouse, but some damaged fruits reach market.

(See 15, 36, 42, 70, 77, 82, 86, 111, 144, 160, 173, 187, 191, 192, 193.)

Drought Injury

Drought injury primarily affects Italian prunes grown in the Northwest, although the disorder is found occasionally on prunes from California, New York, Utah, and other States.

Symptoms of injury are irregular or circular, purple patches on the skin, which later turn brown. The flesh beneath the affected areas may also turn brown; is usually very firm because of dead, corky tissue; sticks to the pit; and often develops gum pockets. Finally, the skin breaks over the pockets, forming cracks $\frac{1}{4}$ to $\frac{3}{8}$ inch long. The cracks are usually on the cheeks of the fruit and release a gummy exudate. Affected fruits usually are culled in the orchard or packinghouse, but occasionally reach market.

Shriveling (see p. 40) is another type of drought injury. Shriveling usually occurs at the stem end of the prune and may extend $\frac{1}{4}$ to $\frac{1}{3}$ the length of the fruit. The flesh beneath the shriveled area turns brown to black. This type of injury is probably due to the withdrawal of water from the fruit by the leaves in times of water shortage.

The effects of drought injury and heat injury (see p. 36) are difficult to separate because of the similarity of certain symptoms.

Losses from drought injury can be reduced by using vigorous root stocks, by proper soil management, and, in irrigated orchards, by proper irrigation practices. Trees that have been injured previously by cold weather may bear fruit showing symptoms of drought injury. Drought injury is often associated with boron deficiency, the tissue and pits of affected fruit being low in boron content.

(See 20, 37, 78, 155, 160, 194.)

Hail Injury

Stone fruits injured by hail when at an early stage of development have irregular, sunken scars, often with dried segments of skin and flesh around the edges or on the surface. The injury may be in the form of small punctures, shallow gouges, deep punctures, or deep gouges that extend to the pit. During development, the fruit enlarges normally except at the site of the injury, resulting in a misshapen product. Large, gum-filled ducts often form in the flesh beneath hail scars. Injured areas on peaches may have a light-red pigmentation; plums may turn brown at the injury. Hail injury to peaches is usually accompanied by russetting at the scarred area (pl. 9, A and B).

Hail injury occurs only on one side of the fruit—the side exposed to hail while the fruit is on the tree. Fruits injured while young

usually heal over, but sometimes the injured area becomes infected with decay organisms. Fruits injured near maturity usually do not heal and soon become unmarketable.

Severely injured fruits are culled during harvesting or packing, but mildly injured fruits sometimes reach market.

(See 160, 168, 173.)

Heat Injury

Apricots, prunes, and plums are more susceptible to heat injury than the other stone fruits.

PIT BURN.—Heat injury to *apricots* is commonly referred to as pit burn. At first, the flesh near the pit softens while the outer flesh remains firm. In a few days the softened flesh turns brown, but still no evidence of the disorder can be seen externally. Pit burn develops when exceptionally hot weather occurs between the time when the fruit begins to lose its green color and when it becomes ripe enough to harvest. Temperatures of 102° or 103° F. for 2 or 3 days are sufficient to induce pit burn. The disorder may develop at slightly lower temperatures on very vigorous trees. The affected tissue is often attacked by decay-causing organisms (pl. 8, C and D).

INTERNAL BROWNING.—Italian and French *prunes* are subject to a disorder called internal browning, which is thought to be related to weather. First the flesh becomes translucent near the pit cavity; later the affected tissue turns brown and breaks down. In severely injured fruit, the affected area may be quite large and cavities may develop in the flesh near the pit.

Heat injury to prunes occurs when orchard temperatures remain above 105° F. for extended periods. Fruits that are near full maturity are more susceptible to the disorder than less mature fruit. Anaerobic conditions in the inner tissue of the fruit during periods of high temperature are thought to contribute to heat injury in prunes. High temperatures (above 105°) also significantly reduce the specific gravity of prunes, thus lowering their quality.

KELSEY SPOT.—Kelsey *plums* sometimes suffer from a heat-related disorder called Kelsey spot. The disorder most commonly occurs on the distal end of the fruit, although it may occur anywhere on the fruit. Mildly affected plums have a slightly depressed, reddish, well-defined spot, but severely affected fruit have larger discolored areas. The flesh below the spot turns brown, usually about one quarter inch deep, but sometimes the brown tissue extends all the way to the pit.

Kelsey spot also affects other varieties of plum; Japanese plum varieties are more susceptible than European varieties. The disorder is more prevalent on weak trees than on vigorous ones, and orchards with cover crops show less damage than clean-cultivated orchards. At temperatures above 105° F., the incidence of Kelsey spot increases.

(See 35, 55, 67, 68, 84, 85, 88, 105, 106, 116, 146, 154, 194, 195.)

Russetting

Russetting is an abnormal roughening and scarring of the surface of fruit, which characteristically is smooth. It commonly occurs on plums and prunes grown in the Pacific Coast States and occasionally occurs on cherries and nectarines. Russetting may be localized on certain parts of the fruit, may occur in patches or bands, or may cover most of the fruit. Sometimes the disorder is accompanied by deformities in the shape of the fruit, and russeted fruit are usually smaller than normal fruit. Bordeaux sprays tend to make cherries smaller and darker than unsprayed fruit, though such sprays at recommended concentrations do not cause russetting.

There are many different causes of russetting. Frost injury, spray injury, insect damage, the rubbing of young fruit against twigs or branches, and various combinations of weather factors may contribute to russetting.

(See 83, 119, 151, 160, 188.)

Split Pits

Peaches and plums of all commercial varieties occasionally have split pits. Early peach varieties with fruits that develop rapidly are particularly susceptible. Blazing Gold, Springtime, Cardinal, and Royal May are early varieties in which split pits are a problem. Some later varieties such as Red Globe, Fiesta, and J. H. Hale also tend to produce split pits.

Externally, affected fruits are usually flattened somewhat at the blossom end and consequently are more spherical than fruit without the disorder. Sometimes a visible crack in the flesh or the upper end of the stone can be seen in the stem cavity, but in many fruits, the split pit cannot be found until the fruits are cut. Fruits with split pits tend to mature faster than normal fruit, so are more prevalent in the first picking of a particular variety. Such fruit are edible but do not carry as well as normal fruit during marketing and may become infected with various decay organisms. Species of *Alternaria*, *Aspergillus*, or *Penicillium*

may grow on the seed or pit without spreading to the flesh (pl. 9, *H*).

During normal fruit development, peaches undergo three stages of growth: A period of rapid growth during the first 40 to 50 days, a period of slow growth during which the pit hardens, and a final growth swell about 4 weeks before harvest. When abnormal growth of the flesh occurs during the period of pit hardening, the pit is torn apart or split, usually along the dorsal or ventral sides. This abnormal growth may result from weather conditions, an unusually short crop, high nitrogen conditions in the soil, or the inhibition of the downward translocation of foods in the tree. Fruits that develop most rapidly and that have split pits are most often found toward the ends of branches or in the tops of trees.

Cultural practices that promote excessively vigorous and rapid growth should be avoided—particularly with varieties that are susceptible to split pit.

(See 18, 52, 113, 147, 160, 173.)

Storage-Related Disorders

Ammonia Injury

Ammonia injury occurs during precooling or in storage when leaks develop in mechanical refrigeration systems using this gas as a refrigerant. Ammonia enters the fruit through lenticels, through the stem, or directly through the skin.

Peaches exposed to low concentrations of ammonia for a short period develop minute, greenish-black specks. With longer exposures or higher concentrations of gas, the fruit loses its red color and becomes a dull, yellowish green. Severely injured peaches have reddish-brown blotches and large drops of moisture on the surface. Peaches with ammonia injury shrivel rapidly when removed from storage and the flesh turns brown, indicating deep penetration by the gas (pl. 10, *A*).

Injury to nectarines is similar to that of peaches, but the surface tissues of nectarines sometimes become brown and russeted when exposed to ammonia.

Sweet cherries turn dark blue around the lenticels when injured by ammonia. The blue color gradually disappears when the fruit is aerated. In severely injured fruit, the affected tissues turn brown and shrivel.

Plums injured by ammonia have swollen, discolored lenticels, which turn dark blue on red fruit and become sunken and brown after several days (pl. 10, *B*).

Ammonia-induced changes of color from red to blue are thought to be due to pH changes in the cell sap. Increasing the alkalinity of the sap causes the color of anthocyanin pigments to change. Browning, associated with severe injury, is caused by oxidation reactions in damaged cells of the fruit.

Injury from ammonia can be minimized if the gas is removed as soon as possible after a leak is discovered. A water spray in the room is very effective for this purpose because ammonia is highly soluble in water. If water cannot be used, the room should be aerated by whatever means available.

(See 54, 148.)

Freezing Injury

See Freezing Injury, page 44.

Internal Breakdown

Most stone fruits are not stored for more than a few weeks. If stored for longer periods, they are subject to internal breakdown, loss of flavor, discoloration of the flesh, surface pitting, shriveling, and predisposition to decay. Some of these disorders may not be apparent when the fruit is first removed from cold storage, but develop when the fruit is ripened.

Peaches and nectarines can be stored for about 3 weeks at 31° to 32° F. without serious loss of quality. With longer storage periods, the fruit may appear to be normal when removed from storage, but often develops serious internal breakdown when transferred to ripening temperatures. The first evidence of breakdown is a reddish-brown discoloration and a granular texture of the flesh. The discoloration is usually more intense near the pit than toward the surface of the fruit. Later the flesh becomes a darker brown, often with gray-brown water-soaked areas extending from around the pit into the flesh. The graininess increases and the affected flesh has a wooly or mealy texture, is off-flavored, and lacks juiciness. Even in such advanced stages of breakdown, the fruits usually have a normal external appearance. Recent studies show that peaches and nectarines can be stored at 31° to 32° in controlled atmosphere with 1 percent oxygen and 5 percent carbon dioxide for 6 to 9 weeks without developing internal breakdown during storage or ripening. However, with such long periods of storage, decay caused by *Botrytis* or *Penicillium* may develop. These organisms normally do not attack freshly harvested peaches (pl. 9, G).

Peaches and nectarines can be stored for a week to 10 days at 40° F. without developing internal breakdown during ripening.

After 3 weeks' storage at 40°, however, internal breakdown is serious.

Apricots can be stored for 1 to 2 weeks at 31° to 32° F. Apricots packed in polyethylene liners have developed a gel breakdown, off-flavors, and mealiness, probably due to atmospheres with high CO₂ levels.

Plums or fresh Italian prunes can be stored for 3 to 4 weeks at 31° to 32° F., depending upon the variety. Longer storage may cause the development of breakdown, darkening of the flesh, and loss of flavor. Stored Kelsey and Wickson plums tend to develop breakdown, which is more severe at 40° than at the recommended 31° to 32°. El Dorado plums develop a slick, gelatinous texture and suffer a loss of flavor when stored at temperatures above 34° for several weeks. Internal breakdown in plums is very similar to that in peaches, starting near the pit and causing the flesh to become water-soaked and, later, to turn brown. Also, affected fruits become mealy and desiccated and develop off-flavors and abnormal odors. Injured fruits frequently are invaded by various decay-causing organisms. Modified atmospheres with high CO₂ levels have been useful in extending the storage life of El Dorado and Nubiana plums, but some varieties such as Santa Rosa and Wickson may be injured by such atmospheres. The use of dual temperatures, in which the temperature is changed during storage, has shown promise in reducing cold storage injury to some plum varieties (pl. 9, *C*, *D*, *E*, and *F*).

Cherries can be stored for 10 days to 2 weeks at 31° to 32° F. When held longer, they sometimes develop elongated, irregular brownish pits in the skin. The flesh beneath these spots is discolored brown and tends to dry out, leaving small hollow cavities. Affected fruit has an abnormal flavor. Injury is frequently followed by decay. Cherries can be stored three times longer at 32° than at room temperature. A 10 percent CO₂ level in controlled storage atmospheres extends the storage life of Lambert cherries up to 25 days without serious loss of flavor. Cherries of this variety stored longer than 25 days in controlled atmosphere lose quality rapidly and suffer extensive decay when removed from storage.

(See 1, 2, 4, 10, 23, 24, 44, 49, 50, 76, 79, 80, 97, 114, 134, 135, 137, 160, 162, 175, 195.)

Shriveling

Shriveling, due to loss of moisture from the fruit, is a severe problem of all stone fruits. If listed in order of susceptibility to

shriveling, nectarines would be first, followed by apricots, cherries, peaches, fresh prunes, and plums. Defuzzed peaches are almost as susceptible to shrivel as nectarines. Loss of moisture from peaches and nectarines not only detracts from their appearance and eating quality, but loosens the pack within the container, thereby contributing to bruising. Shriveling of sweet cherry stems is a serious factor in their loss of fresh appearance and salability. Shriveling is the most extensive form of deterioration of fresh prunes during storage and greatly impairs the market quality of the fruit.

Most shriveling is due to the evaporation of moisture from the surface of the fruits or stems, but some shriveling is due to loss of moisture resulting from metabolic processes (respiration). Sugars break down into water and CO_2 during respiration.

Moisture loss at a given relative humidity is greater at high temperature than at low temperature and at a given temperature is greater at low relative humidities than at high relative humidities. As long as the temperature of the fruit is higher than that of the air around it, moisture will continue to move out of the fruit into the air because of a vapor pressure deficit, even at 100-percent relative humidity. Rapid air movement around the fruit causes more loss of moisture than slow air movement. Small fruits generally lose weight faster than large fruits of the same kind because small fruits have more surface area per unit weight than large ones and consequently more opportunity for evaporation. Kinds and varieties of fruit have different rates of moisture loss, depending upon the texture of the fruit and the type of peel.

Considering the above temperature–relative humidity relationships, the reduction of moisture loss from stone fruits depends upon the following handling practices: Rapid precooling to bring the fruit down to storage room or transit temperatures as quickly as possible; maintenance of high relative humidities (90 to 95 percent) in precooling and storage rooms; the use of protective packaging, such as waxed liners or polyethylene film liners for boxes, to restrict the movement of moisture from the fruit to the container or to the air outside the container; and control of air circulation to provide maximum movement for quick cooling, but minimum movement for temperature maintenance after the fruit is cooled. Hydrocooling is an effective method of precooling some stone fruits and also serves to moisten wooden containers, thereby reducing their absorption of moisture from the fruit.

Peaches lose about $1\frac{1}{2}$ times as much moisture at 40° F. as at 33° and lose about 8 times as much moisture per hour during pre-

cooling as they do after reaching storage room temperature. Moisture loss is about $2\frac{1}{2}$ times as great at 76-percent relative humidity as at 96-percent. These figures illustrate the value of rapid air cooling or of hydrocooling peaches. Polyethylene liners are effective in reducing moisture loss from peaches and nectarines, but cause increased decay losses unless used in conjunction with a fungicide treatment. Unless ventilated, such liners also may cause injurious modifications of the atmosphere.

Cherry stems are particularly susceptible to shriveling and discoloration and lose about four times as much moisture as the fruit, on a percentage of fresh-weight basis. Delayed precooling and warm, dry environments during wholesale and retail marketing are much more harmful than the normal time spent in storage or transit. Rapid cooling in an air blast causes less moisture loss from the stems than slower cooling in relatively still air. Bruising contributes greatly to the loss of moisture from cherry stems. Polyethylene box liners have been very effective in reducing shrivel of cherries shipped from the Northwest.

Waxing effectively reduces shriveling of certain stone fruits, but in some instances may cause an increase in decay. Waxing of apricots may interfere with normal respiration and thus cause breakdown and off-flavors.

(See 3, 23, 43, 53, 69, 72, 73, 114, 117, 167, 182, 195, 199.)

Sulfur Dioxide Injury

See Sulfur Dioxide Injury, page 46.

Transit- and Handling-Related Disorders

Bruising

Bruising injury is common to all stone fruits, particularly to peaches, nectarines, apricots, and plums, and is one of the most important factors contributing to market losses. Bruising may occur during harvesting, sorting, brushing, packing, car loading, shipping, or in wholesale or retail marketing. The increased use of mechanical harvesting for stone fruits has caused an increase in the percentage of bruised fruits. Because fruits become more susceptible to bruising as they soften, they should be harvested at optimum maturity for shipping. During handling, fruits also should be of uniform maturity, because running mixed firm and soft fruits through a sizing line in a packing house causes much more injury to the softer fruits than running only fruits of near equal maturity. Delaying the time between picking and packing also increases losses from bruising.

Varieties differ in susceptibility to bruising. Springtime peaches, which have a pointed tip or apex, are prone to injury at this part of the fruit, whereas Red Haven peaches tend to soften first at the suture, which favors bruising of this part of the fruit. Peach varieties also differ greatly in overall firmness. J. H. Hale, Rio Oso Gem, and Redtop are notable for their firmness and resistance to bruising, whereas many of the very early varieties and the white-fleshed varieties are relatively soft and susceptible to bruising injury.

Symptoms of bruising vary greatly with the type of injury and the kind of fruit. On light-colored fruit, bruised tissues generally appear water-soaked or glassy at first and later tend to turn brown. Dark fruit, such as some varieties of plum, may not show the discoloration. Discoloration of bruised tissues is greater at high temperatures (70° F.) than at low (35°). Bruised tissues frequently develop off-flavors, are usually softer than uninjured tissues, and dry out when exposed to air. Moderate or light bruising may only blemish the skin, but more severe bruising may cause breaks that provide entry ports for decay organisms. Since many of the fungi causing spoilage cannot penetrate the skin of sound fruit, bruising contributes greatly to these secondary losses from decay. The amount of decay developing in mechanically harvested apricots and peaches, for example, is greater than that in hand-harvested fruit. Bruising also predisposes cherries to scald, a cause of quality loss in processed fruit.

The causes of mechanical injury to fruits are sometimes divided into four classes: cutting, compression, impaction, and vibration.

Cutting commonly occurs when fruits strike the sharp points or edges of equipment or containers; and fingernail cuts may be inflicted during picking, sorting, or packing.

Compression injury occurs when fruit is placed in over-packed, bulging containers, when fruit is packed too deeply in a container, or when containers partly collapse because of weakness, excessively high stacking, or other causes. This type of injury may occur at points where fruits touch one another or where fruits touch the bottom, sides, or lid of the box.

Impaction injury occurs at various places during handling. Warm fruits are generally less susceptible to impaction injury than cold fruits. Speeding up packinghouse equipment may contribute to this type of bruising. Padding conveyors and sorting, sizing, and washing machinery to lessen the force of impacts between fruit and machinery parts has helped to reduce losses from this type of bruising. Care in loading, stripping, and bracing rail-

cars reduces the shifting of individual packages and consequent damage from impacts.

Vibration injury occurs when fruits are packed too loosely in a container and consequently roll or rub against adjacent fruits or packaging materials during shipment or handling. Brushing or drying rollers in packinghouses sometimes cause a similar injury. Cold fruit is less susceptible to this type of injury than warm fruit. Fruits with vibration injury may appear scalded as a result of chafing in transit or during handling. Napoleon cherries or some of the light-colored varieties of plum sometimes show this type of injury. Enzymatic browning of the surface areas of plums injured by vibration may be in the form of irregular patches, may appear as concentric bands around the fruit, or may affect the whole surface of the fruit. The flesh sometimes turns brown below affected areas and becomes desiccated. Vibration injury to apricots resembles that to plums.

Peaches from the Southeastern United States sometimes show black to purple longitudinal streaks, which sometimes coalesce, discoloring large areas of the fruit. This disorder is commonly referred to as *black streak*. The discoloration appears to be caused by packinghouse operations in which fruit may rub, roll, or scrub against other fruit or against equipment. Brushes used to defuzz or rollers used to dry the fruit are thought to contribute to the disorder. When injured areas come in contact with iron salts during washing or hydrocooling, the discoloration becomes more intense. Normally the discoloration does not appear until 20 to 24 hours after the fruit has been packed and is more severe on warm than on cold fruit (pl. 10, *G*).

Pads and box liners reduce compression, impaction, and vibration injury. The tight-fill container has been successful in minimizing injury to cherries, peaches, nectarines, apricots, and plums. Various types of cup and tray materials also reduce injury. Careful handling through all phases of harvesting, shipping, and marketing is an obvious and necessary way of reducing losses from bruising. Prepackaging has helped to reduce injuries incurred during the retailing of stone fruits.

(See 27, 41, 66, 75, 82, 108, 122, 123, 124, 133, 142, 150, 152, 164, 181, 183, 190, 206.)

Freezing Injury

Freezing injury may occur during precooling, in storage, during transit, or during handling at terminal markets. Because most stone fruits are harvested and shipped during the summer months,

freezing usually results from faulty refrigeration practices or malfunctioning equipment rather than from inclement weather. However, exposure to frost in the orchard during the growing period may cause russetting of the fruit, particularly plums or Italian prunes. Susceptibility to freezing varies with the kind and variety of fruit and with the maturity. Fruits with high soluble solids have lower freezing points than those with low soluble solids, and as fruits mature, the soluble solids increase. Also, the stems are more susceptible to freezing than the edible part of the fruit because the soluble solids are low in the stems.

The place in the handling and distribution sequence where freezing damage occurred may be indicated by the pattern of freezing within a container or within a load. For example, containers with frozen fruit scattered at random through a load suggest that the freezing occurred before loading the fruit in the railcar or trailer. On the other hand, containers with frozen fruit located near the outlets of refrigeration ducts or adjacent to the walls of a car or trailer suggest that the freezing occurred during transit. Sometimes only the fruit at the sides of the containers adjacent to a wall of the car or trailer is frozen; this pattern also would suggest freezing during transit.

Symptoms of freezing injury are a water-soaked, translucent appearance of the skin or the flesh. The severity of freezing depends upon the temperature drop and the length of time below the freezing point. When ice crystals form in the tissue, the cells are crushed or ruptured. The tissues collapse, turn brown, and become soft and mushy. Severely injured fruit is often sticky because of leakage of juice from the injured tissue.

Cherries have average freezing points ranging from 26.2° to 28.2° F., but freezing points may be slightly higher or lower, depending on maturity. The stems may be injured at temperatures only slightly below 32° .

Peaches have average freezing points ranging from 29.0° to 30.1° F. A low point of 28.4° and a high of 30.3° were found in different varieties (pl. 10, *F*).

Nectarines have average freezing points ranging from 28.8° to 30.0° F. A low point of 27.7° and a high of 30.4° were found in different varieties.

Apricots have average freezing points ranging from 28.9° to 29.9° F. A low point of 28.6° and a high of 30.1° were found in different varieties.

Plums have average freezing points ranging from 27.2° to 29.8°

F. A low point of 26.3° and a high of 30.5° were found in different varieties.

(See 114, 201.)

Shriveling

See Shriveling, page 40.

Sulfur Dioxide Injury

Sulfur dioxide injury occurs when stone fruits are stored or shipped with table grapes, which are regularly fumigated with the gas to control decay. Vinifera grapes are about the only fruit not injured by sulfur dioxide. The injury to stone fruits occasionally occurs in storage if the gas accidentally moves through ducts or other openings from a room used for grapes to one used for other fruits. More often, the injury occurs in a mixed load of grapes and other fruits, which are fumigated in a railcar or trailer. The person responsible for fumigating the grapes may not know that other fruits are in the same load.

Sulfur dioxide injury has been observed on cherries, peaches, nectarines, and plums. The gas causes pitting and bleaching of all these fruits. Injured areas turn brown, especially when the fruits are removed from refrigeration. On cherries and plums the injury occurs at the lenticels, but on peaches and nectarines the injury occurs anywhere on the surface of the fruit. On peaches the tissue collapses beneath the browned areas, causing them to lose moisture and become sunken. Sometimes the skin of peaches sloughs off when injured by sulfur dioxide (pl. 10, C, D, and E).

(See 56, 160.)

INSECT INJURIES

Damage to stone fruits by insects, once very common on the market, is now rarely found because of improved methods of controlling insects in the orchard, better sorting and grading of fruit, and generally improved handling and marketing methods. Some injuries caused by insects are difficult to distinguish from plant diseases or physiological disorders, and fruit so injured occasionally is found on the market.

Catface

Peaches and other stone fruits may be pitted, dimpled, scarred, or otherwise distorted as the result of damage by sucking bugs.

Severely distorted or "catfaced" fruits result from injuries that occur when the fruits are small, and subsequent growth of tissue around the injured areas causes the abnormally shaped fruit. Injuries that occur when the fruits are larger cause less distortion and result in dimpled or pitted fruits. Such fruit are sometimes mottled since the skin at the bottom of the dimples remains green. Peaches injured near maturity may develop dried out, corky areas around the feeding sites of the insects. Injuries from sucking bugs may occur anywhere on the surface of the fruit, but most often are near the stem end. Injuries form entry ports for brown rot and other decay organisms. The insects that cause catface usually have left the fruit when the injury becomes apparent. Consequently, the kind of insect causing the injury is difficult to determine (pl. 8, E).

Several kinds of insects cause catfacing. The tarnished plant bug (*Lygus lineolaris* (Palisot de Beauvois)) occurs throughout the United States and seriously injures peaches. In California, a lygus bug (*Lygus hesperus* (Knight)) causes catfacing in peaches and nectarines. The brown stinkbug (*Euschistus servus* (Say)) and the green stinkbug (*Acrosternum hilare* (Say)) are widespread in the Southeastern United States, the former causing catfacing and the latter dimpling, since the green stinkbug usually feeds on peach fruits after they have already enlarged. The Conspersed stinkbug (*Euschistus conspersus* Uhler) and the Say stinkbug (*Pitadia sayi* (Stal)) cause catfacing in California. The former also causes dry, corky areas to develop under the skin of peach, apricot, and plum fruits. Several other species of sucking bug may cause catfacing. Under some conditions the plum curculio (*Conotrachelus nenuphar* (Herbst)) causes a similar injury to stone fruits. Injury by this insect may result from either egg punctures or feeding. Heavy infestations of thrips (see p. 49) sometimes cause catfacing of nectarines in California.

Many of the sucking bugs hibernate as adults in winter, becoming active in the spring. Certain species predominate at bloom, others are most abundant a few weeks after bloom, and some are present during the entire growing season. Since weeds, cover crops, and orchard trash favor the build-up of these pests, ridding the orchard of these breeding places is helpful in reducing injury. Cultivation also interrupts the life cycle of the plum curculio. An insecticide recommended by the local agricultural agent should be applied at bloom time and at intervals thereafter to reduce injury.

(See 214, 216, 217, 218, 219, 220.)

Fruit Gumming

"Gumming" frequently occurs at sites of insect activity on stone fruits. The exudation of gum from the tissues of the fruit may be stimulated by the feeding of adult insects, the entrance or exit of larva from the fruit, or the deposition of eggs beneath the skin of the fruit. The rupture or puncture at which gumming may be partly surrounded by a crescent-shaped slit, which persists on smooth-skinned fruits such as plum, but generally disappears on developing peach fruits. Fruits injured early in their development tend to exude large quantities of gum, whereas those injured late may not heal at all and are subject to decay. The incidence of brown rot is closely correlated with insect injuries. Sometimes the injury does not appear to be extensive on the surface, but a large cavity may occur beneath the opening or the flesh may be almost completely consumed by larvae within the fruit (pl. 8, *E*).

Certain bacterial and fungal diseases may also cause gumming. These diseases, however, are readily distinguished from insect injuries, which are characterized by tunneling within the flesh, the presence of a powdery frass, or the larvae themselves.

Several species of insect may cause gumming of stone fruits. The adult plum curculio frequently feeds on young peach fruits and the females lay their eggs in the fruit. The larvae develop within the fruit, which then tends to drop from the tree. The oriental fruit moth (*Grapholitha molesta* (Busck)) also causes gumming but the larva is the only injurious stage of this insect. The larvae enter the partly mature fruits through either the stems or the sides and feed on the flesh near the pit. Peaches are injured most by this insect, but other stone fruits also may be attacked. The oriental fruit moth is an important cause of gumming in peaches grown in both the Eastern and Western United States. The larvae of the peach twig borer (*Anarsia lineatella* Zeller) attack the fruits of peach, apricot, and plum. The peach twig borer is most serious on the Pacific Coast although it also causes loss in other stone-fruit growing areas of the United States.

The peach twig borer is controlled by dormant sprays in some localities, but in California additional bloom and postbloom sprays are recommended. The oriental fruit moth and the plum curculio are more difficult to control, requiring additional sprays during the growing season and good orchard sanitation to eliminate the culled fruit in which larvae develop. Clean cultivation of orchards helps reduce the population of these insects.

(See 214, 215, 216, 217, 218.)

Thrip Injury

Thrip injury is confined to the surface of fruits. Cherries, peaches, nectarines, apricots, plums, and prunes are sometimes scarred or russeted by thrips, particularly in the Pacific Coast States and to a lesser extent in the Eastern United States. Nectarines and prunes are injured more often than other fruits. Thrips feed by rasping the surface of the fruit or other plant parts and sucking out the sap exuded from the injured cells. They also injure young fruit by depositing eggs in the stems, which usually causes the fruit to drop. Injury often occurs where leaves or flower parts touch the fruit, the thrips feeding on both the protected leaf and fruit surfaces. Fruit damage is greatest during the interval between petal fall and shedding of the calyx. The injury appears as a stippling, mottling, russetting, or silvering of the skin, which is generally lighter in color than unaffected areas of the fruit. The discolored area may be whitish, grayish, or yellowish, depending upon the background color of the fruit. Nectarine fruits that are severely injured when small may become distorted as they mature. Injured areas on smooth-skinned fruits, such as prune or nectarine, frequently become checked or pitted (pl. 8, G).

Several species of thrips may injure stone fruits. The pear thrip (*Taeniothrips inconsequens* (Uzel)) commonly injures prunes in the coastal valleys of California. The western flower thrip (*Frankliniella occidentalis* (Pergande)) commonly injures stone fruits in central California.

Thrips usually do not cause sufficient damage to warrant the application of insecticides. However, either prebloom or residual bloom sprays provide effective control. Clean cultivation of orchards and elimination of weeds help reduce thrip populations.

(See 213, 215, 216, 217.)

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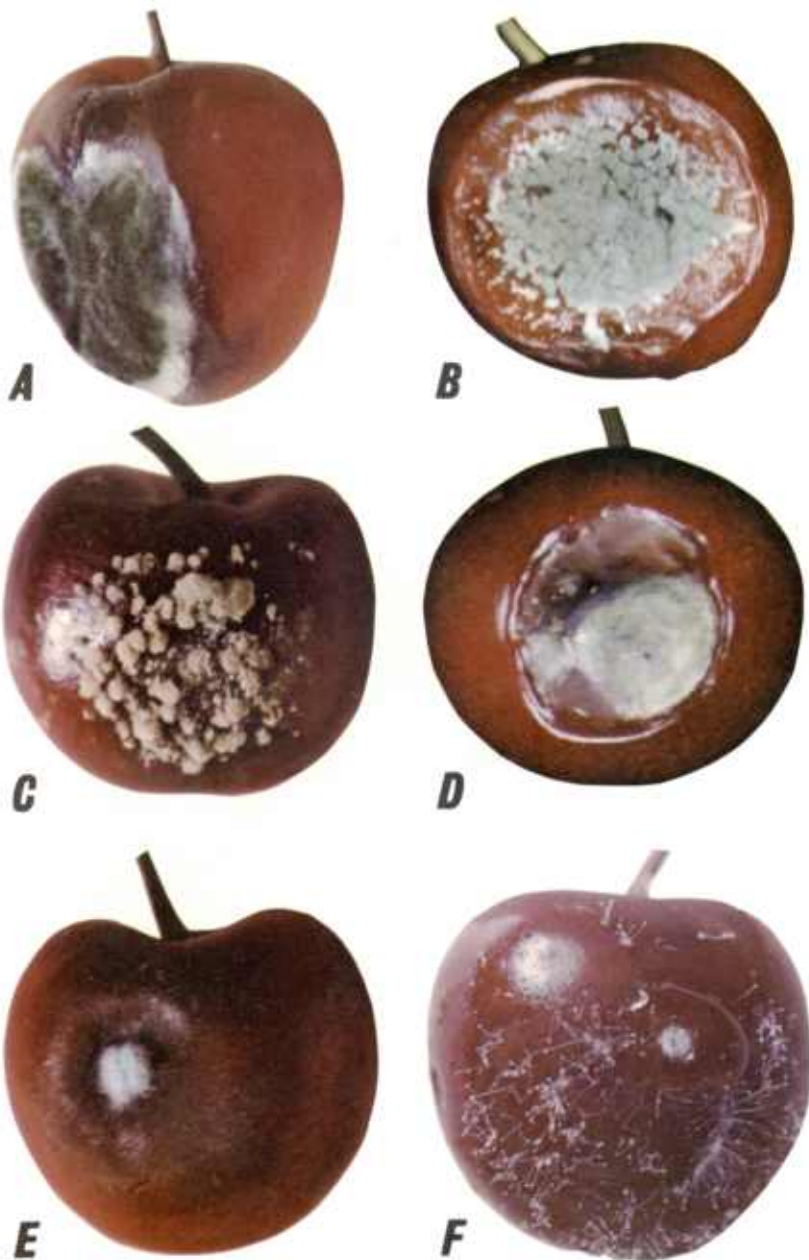
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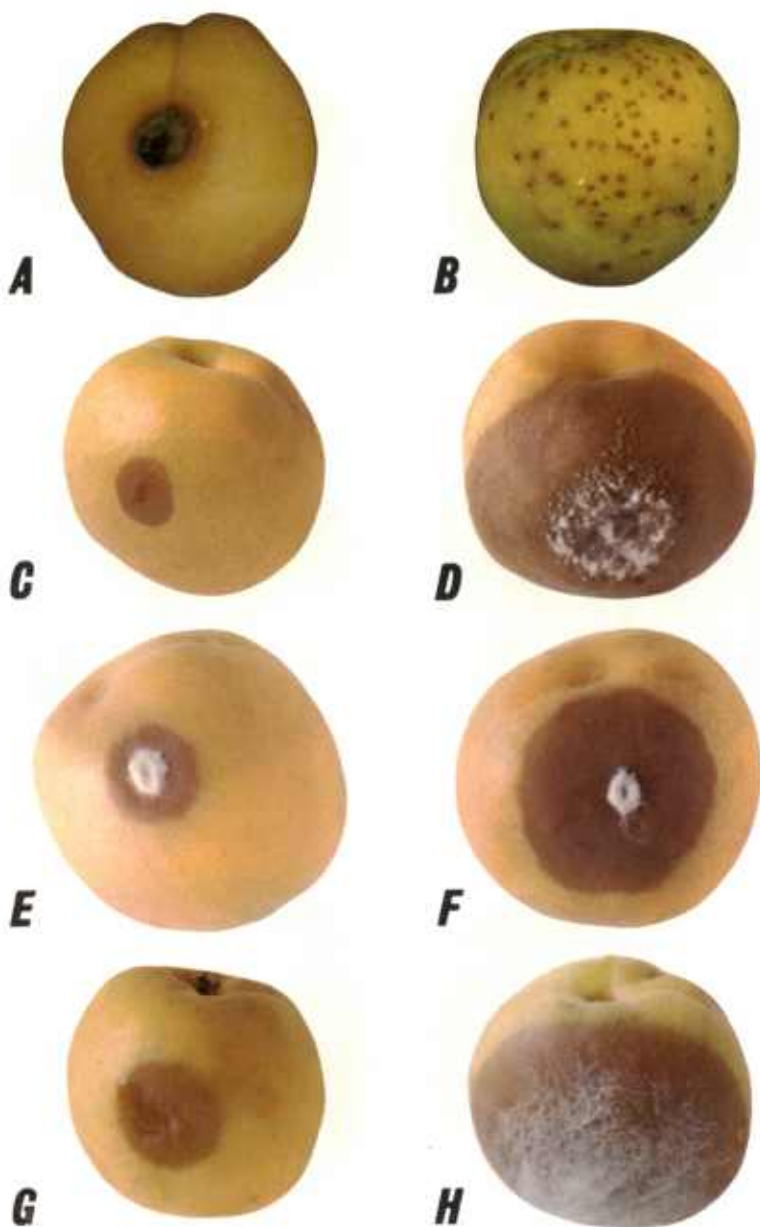
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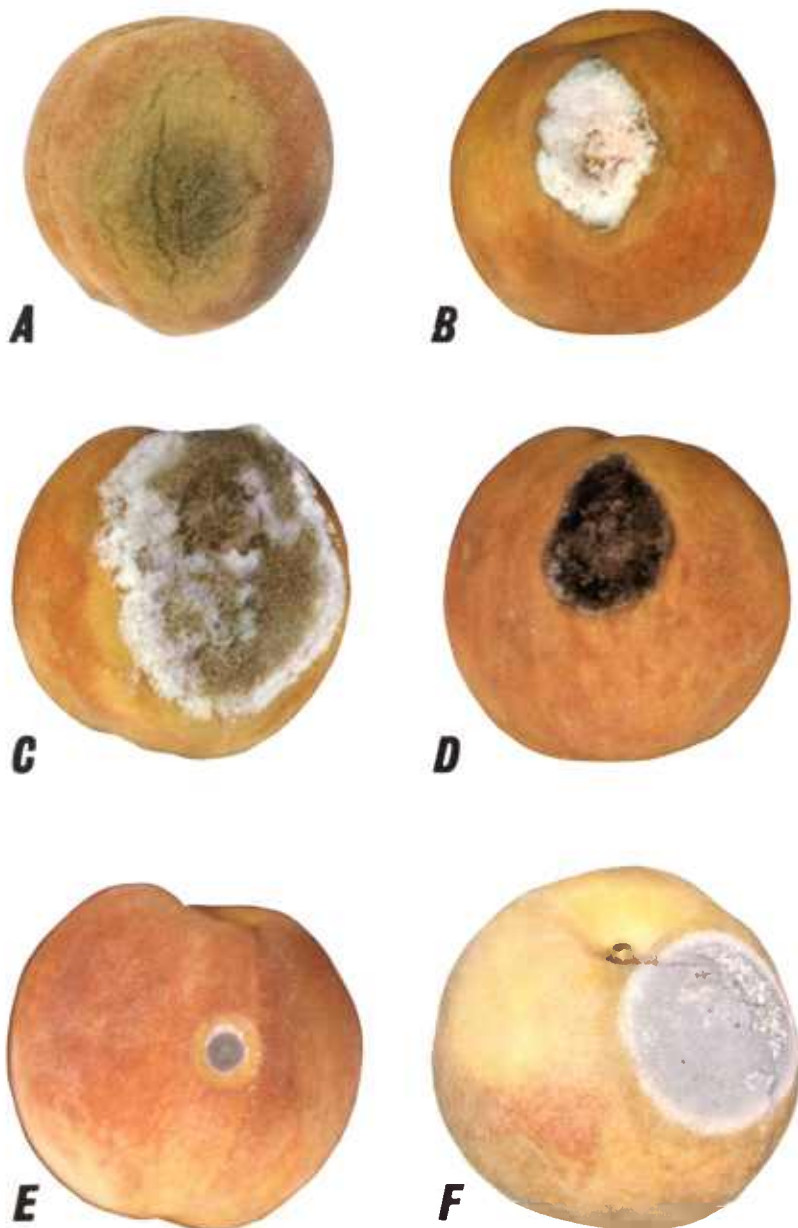
PARASITIC DISEASES OF CHERRY

A, *Alternaria* rot of cherry ; B, Blue mold rot of cherry ; C, Brown rot of cherry ; D, *Cladosporium* rot of cherry ; E, Gray mold rot of cherry ; F, *Rhizopus* rot of cherry.



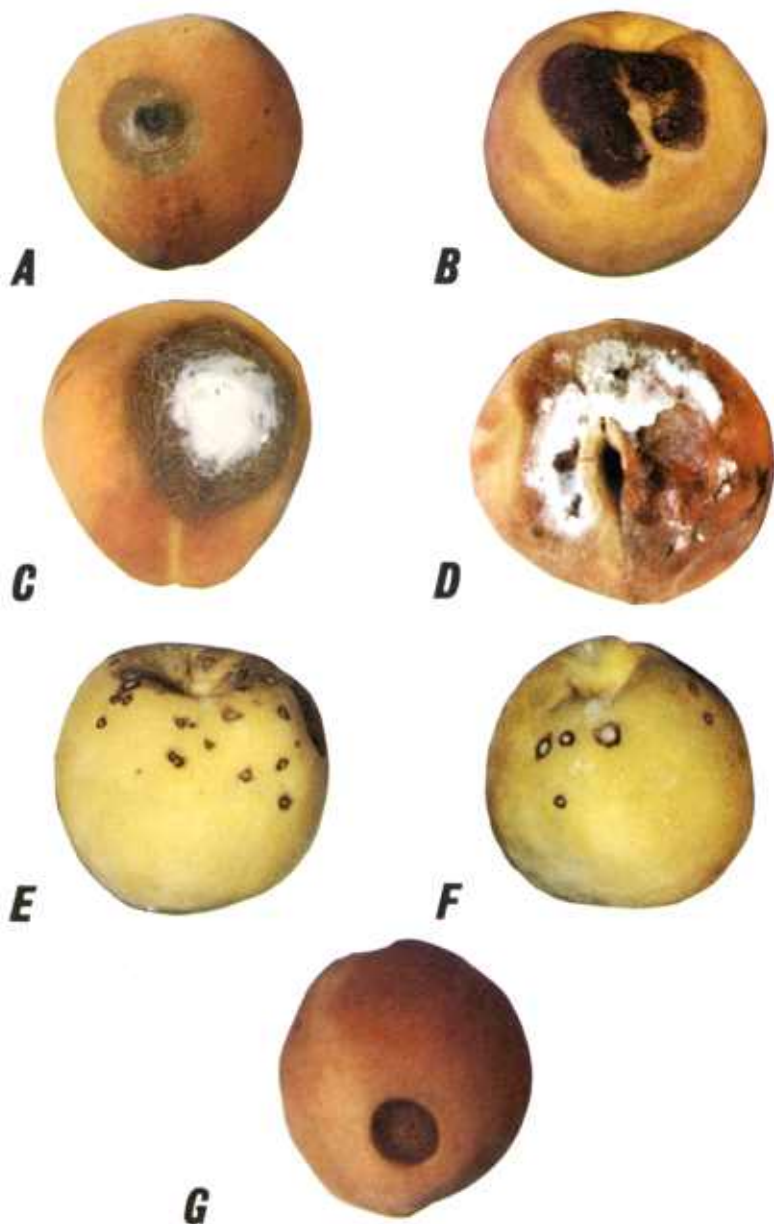
PARASITIC DISEASES OF APRICOT

- A, *Alternaria* rot of apricot; B, *Coryneum* blight of apricot; C, Brown rot of apricot (early stage); D, Brown rot of apricot (late stage); E, Gray mold rot of apricot (early stage); F, Gray mold rot of apricot (later stage); G, *Rhizopus* rot of apricot (early stage); H, *Rhizopus* rot of apricot (late stage).



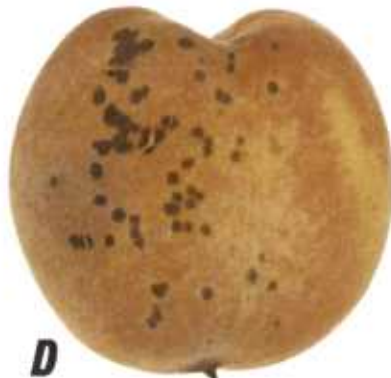
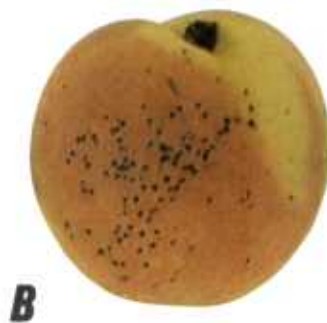
PARASITIC DISEASES OF PEACH

A, Gray mold rot of peach (early stage) ; B, Gray mold rot of peach (intermediate stage) ; C, Gray mold rot of peach (advanced stage) ; D, Alternaria rot of peach ; E, Blue mold rot of peach (early stage) ; F, Blue mold rot of peach (advanced stage).



PARASITIC DISEASES OF PEACH

A, Black mold rot of peach (early stage) ; *B*, Black mold rot of peach (advanced stage) ; *C*, *Diplodia* rot of peach ; *D*, Sour rot of peach ; *E* and *F*, *Coryneum* blight of peach ; *G*, *Anthraco*se of peach.



PARASITIC DISEASES OF PEACH

A, Bacterial spot of peach (early-season infection) ; *B*, Bacterial spot of peach (late-season infection) ; *C*, Peach scab (early-season infection) ; *D*, Peach scab (late-season infection) ; *E*, Powdery mildew of peach (on green fruit) ; *F*, Powdery mildew of peach (on ripe fruit).

**A****B****C****D****E****F**

PARASITIC DISEASES OF PEACH

A, Brown rot of peach (early stage) ; B, Brown rot of peach (intermediate stage) ; C, Brown rot of peach (advanced stage) ; D, Rhizopus rot of peach (early stage) ; E, Rhizopus rot of peach (intermediate stage) ; F, Rhizopus rot of peach (advanced stage).



A



B



C



D



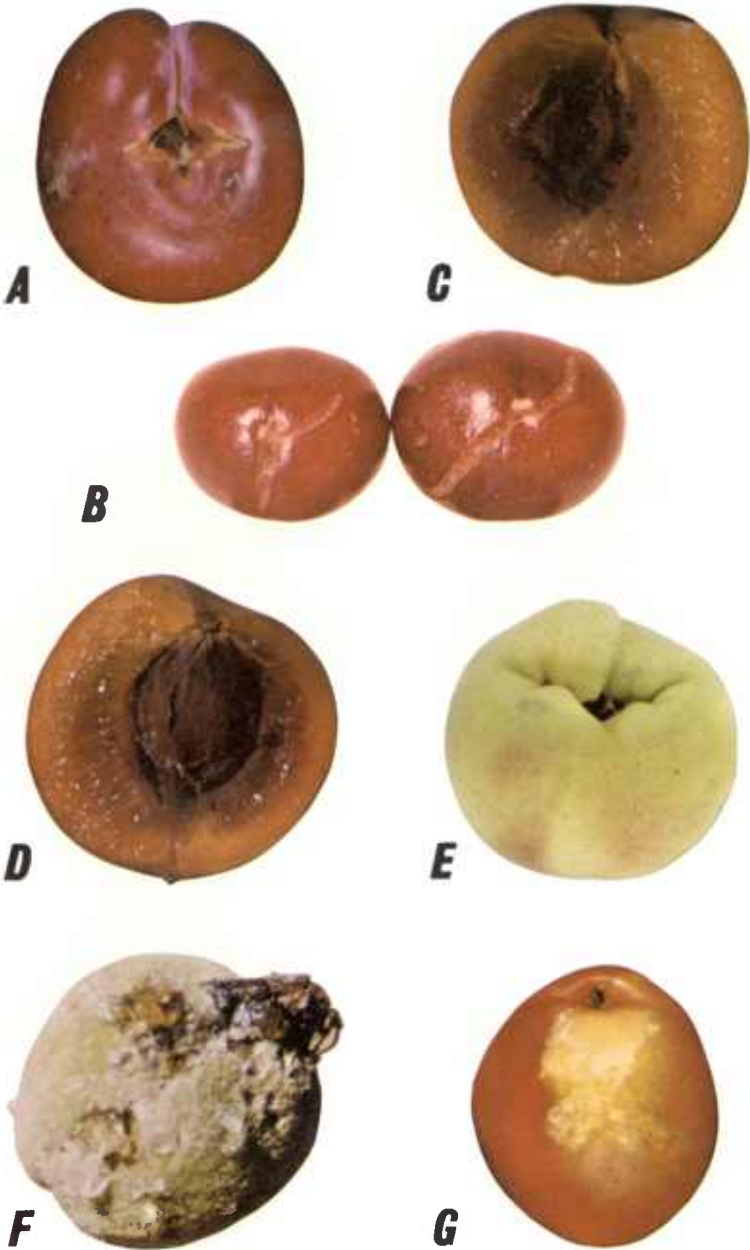
E



F

PARASITIC DISEASES OF PLUM

A, *Alternaria* rot of plum; B, Blue mold rot of plum; C, Brown rot of plum; D, *Cladosporium* rot of plum; E, Gray mold rot of plum; F, *Rhizopus* rot of plum.

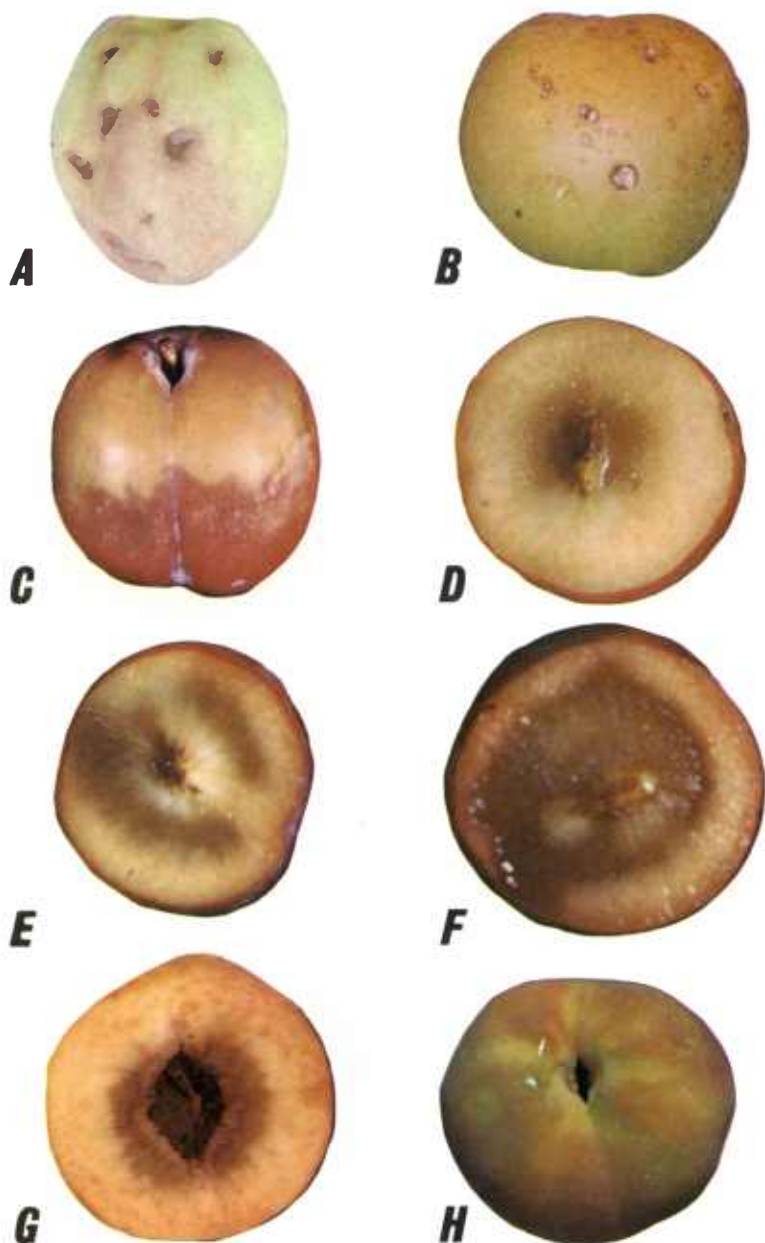


NONPARASITIC DISEASES

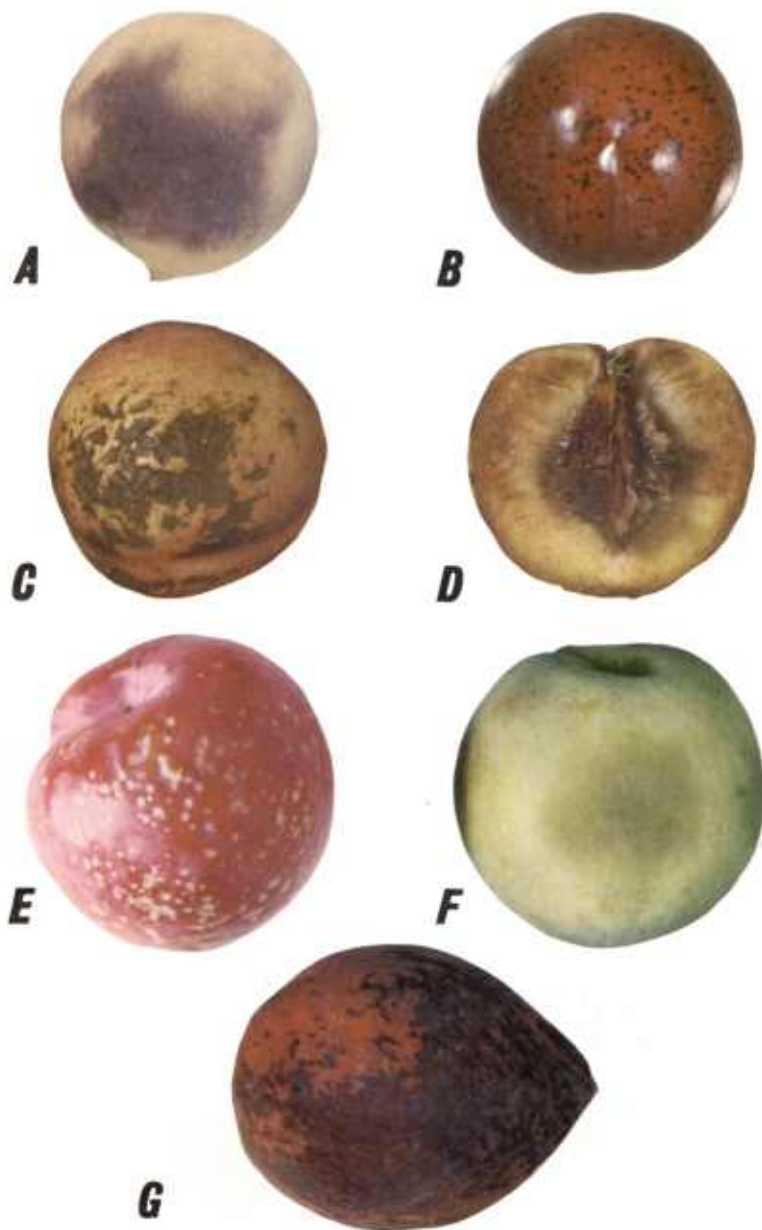
A, Cracking of plum ; *B*, Cracking of cherry ; *C* and *D*, Pit burn of apricot.

INSECT DAMAGE

E, Catface of peach ; *F*, "Gumming" of peach ; *G*, Thrips damage of nectarine.



A, Hail injury to peach (early-season injury) ; **B**, Hail injury to apricot (late-season injury) ; **C**, Physiological (internal) breakdown of plums (external symptoms) ; **D**, **E**, and **F**, Physiological (internal) breakdown of plums (internal symptoms) ; **G**, Internal breakdown of peach ; **H**, split pit of peach.



NONPARASITIC DISEASES

A, Ammonia injury to peach; *B*, Ammonia injury to plum; *C* and *D*, Sulfur dioxide injury of nectarine; *E*, Sulfur dioxide injury to plum; *F*, Freezing injury to peach; *G*, Black streak injury to peach.